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The Role of the Amateur in Scientific Discovery

The history of science bulges with the achievements of amateurs. So striking is this phenomenon that at times it seems almost as if one of the requirements for scientific discovery is initial ignorance. Undoubtedly there are reasons for this anormality, which it may be profitable to seek.

An amateur is one who is not a professional specialist. Hence a specialist in one field usually is an amateur in all other fields of knowledge. Thus regarded, it is seen that Isaac Newton must have been an amateur in nearly all the realms of science that were enriched by his discoveries. He was a professor of mathematics at Cambridge, and he remained an amateur in every other branch of science. True it is that he made some of his most profound discoveries in his own professed specialty. His development of the infinitesimal and integral calculus was an epochal achievement. But equally true is it that he revolutionized astronomy, in which he started as an amateur and remained always an amateur. Except for an occasional peek of curiosity, Newton scanned no stars through telescopes. He was content to take the data and empirical laws of Tycho Brahe, Kepler et al, and, by their suggestive guidance, deduce the law of gravitation together with its most important sublaws. Then he turned to the realm of physics which he enriched with his discoveries in optics and acoustics. He wandered from cave to cliff in many a different scientific realm, everywhere finding new nuggets of knowledge, as amazing in their richness as in their variety. Par excellence Newton was the amateur in science, yet always out stripping his contemporary professionals.

Shall we attribute this merely to genius, that word with which we cloak our ignorance of the methods of the original thinking? Or shall we try to find the principles employed by original thinkers, and the conditions under which original thought is best conducted?

Let us consider some of the conditions that assist the original thinker. One of these clearly is an unbiased attitude, a freedom from old theories that so dominate the mind as to blind it to the truth of new theories. It is characteristic of most professional men that they become exceedingly intolerant of new theories. The longer they believe in an old theory, the more intolerant they are of a new theory that conflicts with the old. While a new, true theory has a marvelous efficacy in solving scientific enigmas, an old, false theory is equally effective in turning the mind away from correct solutions. Here, too, the history of science is replete with examples.

The amateur therefore enjoys a not mean advantage over the professional, in that he is not handcuffed to any corpses. His mind's eye moves freely and quickly over hypotheses; the new being as impartially regarded as the old. He pauses with no sense of "auld lang syne" amid well known theories, but is impressed by them only, in so far as they match and explain the facts of nature. So, new and old theories look much alike to the amateur, whereas to the professional only the old cause him to lift his glass and say: "May you live long and prosper."

Great as is the importance of having a mind not initially biased by old theories, there is a much more important advantage possessed by the amateur researcher, namely the fact that he is instinctively a researcher. If he may be called a "professional" in any sense other than the common sense of earning a livelihood by a given kind of activity, the amateur investigator is a professional researcher. He is an animated interrogation point. Why this? Why that? Why the other thing? Now this characteristic is precisely the one not yet common among men. So it follows that when an amateur who is a researcher by instinct enters any realm of science, he often finds himself almost alone as to originality. What wonder then that his work soon becomes conspicuous. He encounters, of course, the ill concealed skepticism of many professionals, who at first can see in him only the amateur. Witness Louis Agassiz's announcement that he had discovered that an ice-age had existed over Europe not many thousand years ago. Professors of geology were not slow in writing him to "stick to his fishes," piscatology being his profession. Even that great migratory mind, Humbolt, solemnly adjures him not to wander into the realm of geology. But he persisted in

wandering, until he soon had all the world wondering. He had discovered a new fact of undreamed of importance, namely that climate has changed enormously. Indeed this phenomenon is one of the most important factors in biological evolution. Had there been no ice ages there would be no man, and but few of the countless species of animals and plants that now ride this spinning top of time.

Not long before Agassiz's epochal discovery, another amateur, an English county surveyor, had made a geological discovery equally great. William Smith had noticed that fossils in different rock strata differ, and he formed the hypothesis that each formation represented a geological epoch, in which different species of animals had lived. He made the first stratigraphic map ever made, and associated each formation with its characteristic fossils. His friends dubbed him "Strata" Smith, and called him "that crank." But this professional surveyor was destined to evolutionize the science of geology which was then in its infancy.

Stepping forward a century we meet an amateur of the amateurs, a young lad in his teens, not yet decided as to a profession, Luther Burbank. We see him reading Darwin's "Origin of Species," and beginning to wonder whether a man might not be able to create a new species by artificial selection even as nature had created new species by natural selection. We see him resolve to try the impossible. He starts humbly enough by developing the Burbank potato. No horticulturalist, no professsor of biology or botany here—just a New England country-town boy; but he was soon to make the naturalists of the world admit that man at last had rivalled nature by producing an entirely new species of plant.

Willard Gibbs, professor of mathematics at Yale, did not stick to his pure mathematics, but chose to wander into the field of physics where he discovered the "Gibbs phase law" that has been such an invaluable aid to research chemists that it has been termed the philosopher's stone of modern chemistry.

Gregor Mendel, a name long forgotten but now engraved large on the portals of biology, was a monk who did not confine his thoughts to religion, but sought to discover the laws of heredity. Experimenting with flowers, by crossing different strains, he uncovered what is now known as the Mendelian law of heredity.

A large book could doubtless be filled with just such biographical paragraphs as those above, each stating concisely the scientific discovery of some amateur.

Lest it be assumed that we regard the professional expert as being irretrievably handicapped by his expert knowledge, as Henry Ford seems to think, we hasten to add that it is not his knowledge that handicaps him so much as his tendency to rest satisfied with what he knows. Supplement such a tendency with an inclination to regard original research work as being beyond their powers, and you have quite a complete explanation of the paucity of discoveries by professional men.

Two generations ago German teachers of science, particularly chemistry, began to stress training in original research. The results have been so prolific that we may well wonder why American teachers have been so slow in following German practice.

If it be argued that education is primarily designed for the man who is not an original thinker, but for the average man, then the argument assumes that most men lack an instinct for originality, which is a false premise. Original thinking differs not one whit in principle from what is regarded as unoriginal or ordinary thinking, except in degree of originality. In every case of real thinking a problem presents itself for solution, and calls for the gathering of facts, then systematic classification and inferences as to what they signify. It calls also for the memorizing of many of the facts, so that the mind will have material upon which to work; but so far removed from correct understanding of psychology are most of our teachers that they actually inveigh against loading the memory with details, than which no greater error has ever been made. Our Edisons and our Burbanks have always been walking encyclopedias, loaded to the eyes with facts. So, too, are most successful men in every walk of life. It used to be said of James J. Hill that he knew every last penny of railway transportation costs, and the why of every detail. The one time that the editor heard him lecture to an audience of business men who asked him many questions it was the general verdict that they had never heard such a demonstration of the power to remember details. Yet, in the face of innumerable cases of this sort, most teachers go on decrying the teaching of anything much except "general principles." General principles never won even a skirmish without a regiment of those privates that we are prone to belittle as "mere details."

It is by observing some slight similarity between two details of different phenomena that the kinship of the phenomena is first suspected. And it is by marshalling more details that the better known phenomenon serves to guide the investigation to a theory that explains the less well known phenomenon. Exactly the same process leads to success in solving business and professional problems. Hence it is a mistake to think that German training in research work is not the kind adapted to the needs of the average man. Our firm conviction is that it is the only kind of mental training that has much merit. And it is because certain amateurs have been trained or have trained themselves in that manner that they are able quickly to solve original problems in fields that are new to them.

Let it also be noted that it usually requires only a few weeks of intensive reading to master all the theories and facts relating directly to any limited branch of scientific knowledge, and it becomes apparent that an amateur can possess himself of more knowledge about it than most professionals have. Then if the investigator has read widely in science and has remembered much that he has read, he is equipped to attack a problem in that branch of knowledge with excellent chance of successful issue.

H. P. Gillette

An Electromagnetic Whirl Theory of the Genesis of Planets

Explaining Geological and Topographical Formations, Barometric and Climatic Changes

By HALBERT P. GILLETTE

THE genesis of the solar system, and of other planetary systems, will be outlined first. Quantitative laws of planet periods of orbital revolution and of axial rotation will be given next. It will be shown that the great magnetic whirls called sunspots have their counterparts not only in cyclonic storms on the earth, but in whirls that existed in the molten matter of our globe. By their sunspot effects 11 planets have been discovered, several of which have been predicted, and one of which, Vulcan, has even been claimed to have been seen.

These and other phenomena will be shown to be caused by electromagnetic propulsion. Hence it follows that not even gravitation itself has been a more important factor in the architecture of the universe than has been the force called electricity.

It has long been known that electric currents moving in the same direction attract one another, while those moving in opposite directions repel one another, and that under certain conditions electric currents are magnetically rotated. The present article deals mainly with rotating masses, all of which are electrified to some extent by the presence of "free" electrons, and are therefore electromagnets. These may be called electromagnetic whirls, to use a generic term.

A Basic Principle.—It was established in 1876 by Rowland that a whirling metal plate charged with static electricity acts as if an electric current were flowing in circles about the center of rotation. Later, when the electron was discovered, it was evident that whether an electron is attached to a moving mass or is itself moving independently (as along a conductor), an electric current exists, with its concomitant magnetic effects. But, curiously, these facts have been given scant consideration either in the realm of astronomy or of metereology. It is true that Hale has shown that sunspots rotate and are powerfully magnetic, but this very important discovery has remained almost isolated and unused.

The Electron.—Atoms consist partly of electrons travelling in orbits about a nucleus that may itself be nothing else than a very great number of orbital electrons packed into an exceedingly small space. Atoms release electrons, probably from the nucleus, the number released (or made "free") depending upon the kind of atom, the external radiations to which it is subjected, its temperature and the pressure upon it. The higher the temperature and the lower the pressure the greater the number of free electrons.

A Great Force.—Even among scientific men few seem to know how stupendous is electric force compared with gravitative force. The electric attraction of an electron is to its gravitational attraction as $\frac{1}{4} \times 10^{40}$ is to *1;* or the electric force is 2,500,000,000,000,000,000,000,000,000,000,000,000,000 times the gravitative force of an electron. Hence even a very few free electrons in motion may be expected to show enormous power, and they do.

It is probable that no large mass exists that is devoid of some free electrons, and consequently of some electromagnetic force.

Molten whirls, as will be shown, have been the architects that have given to our globe its general topographical form. Air whirls have caused the climatic and weather cycles that, by causing rainfall, have created the sedimentary rocks and carved both the sedimentary and the igneous uplifts into multitudinous shapes.

Were it impossible to support this whirl theory in its every ramification by quantitative facts, it would be only a suggestive hypothesis at best, but the theory is supportable by so many statistical facts that only a small percentage of them can be given in an article of moderate length. However, it is believed that the facts here given will suffice to show that this electromagnetic whirl theory of the genesis of rotating and orbital masses is sound in principle and far reaching in its applications.

Planet Genesis.—As Hale has shown, sunspots are magnetic whirls in the sun's atmosphere. Free electrons tend to move along the lines of force of a magnet, hence it is probable that ionized molecules are similarly propelled. At any rate, it is certain that along the axis of a sunspot material is ejected to great heights, and presumably some of the material thus ejected travels great distances into space, propelled by electromagnetic energy. Some of the material thus ejected would necessarily be halted in its outward flight by the counter pressure of electromagnetic force of other stellar bodies, and would thereafter pursue an orbital path.

If we regard a sunspot as a rifle shooting sundust into space, some of which dust is halted by counter radiations from another sun, three effects become inevitable: First, orbital bodies

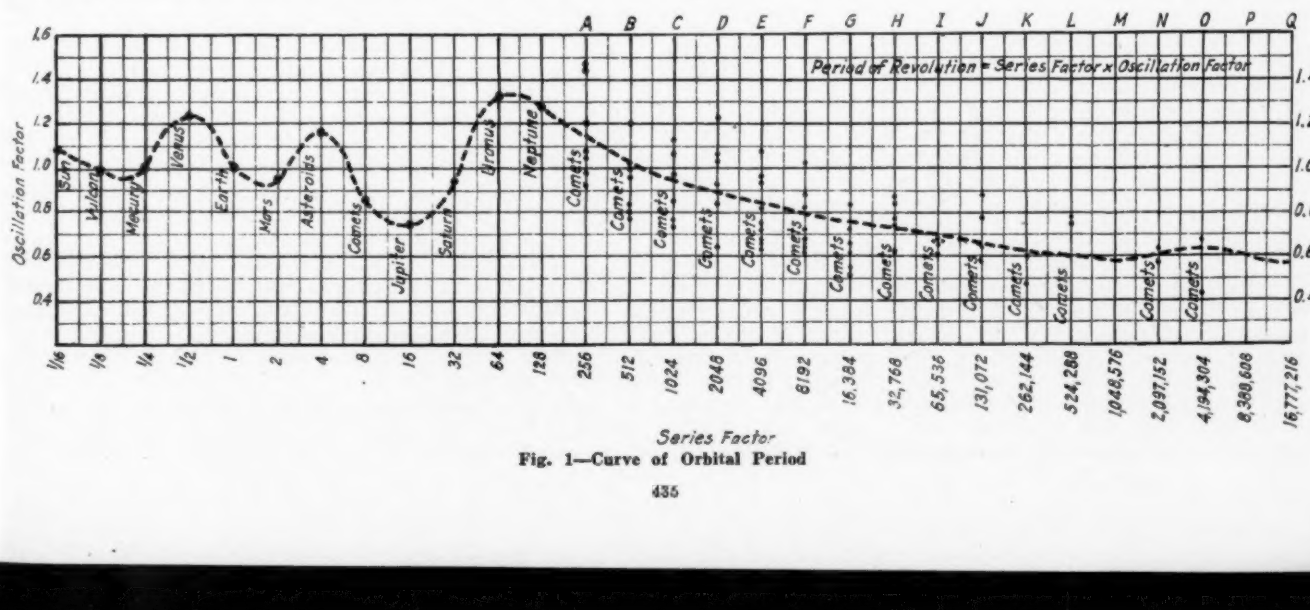


Fig. 1—Curve of Orbital Period

are created between the two suns, and those orbital bodies grow fastest that have orbital periods that are in a geometric series in which the sun's period of rotation is unity, with the orbital period of the first planet double the rotative period of the sun, and the orbital period of each successive planet double that of its predecessor. Second, the diameters of the successive planets in the series must be proportional to their mean distances from the sun, if the process of planet building is not halted, and if the rotative velocity of the generating sunspots remains constant. This means that the diameter of each planet in such a series is such that it exactly eclipses the successive planets and the distant sun. Third, as each planet becomes radiant it acts as a sun itself and halts material ejected from the sun.

Titius-Bode Law.—That some sort of a geometric series of planet distances exists was evident to Titius and Bode, who crudely expressed it in the Titius-Bode law. Unfortunately they made their doubling factor relate to distance, whereas it really relates to orbital period, so their law is but a crude first attempt at a solution of the problem, unguided by any rationalization. Study of the moons and planets shows at once the substantial truth of the geometric series of their periods and it also discloses that in some instances the multiple is 1.5 instead of 2.

The fact that our moon almost exactly eclipses the sun points to the truth of the second generalization; but even more significant is the fact that the diameters of Mercury, Earth and Saturn are very nearly proportional to their solar distances. A similar law is seen to hold approximately as to the moons of the planets.

Another Variable.—There is, however, at least one other variable to be considered, for not all the planets have diameters proportional to their solar distances, nor are their periods exactly double those of their predecessors in the series. A little consideration shows that a variable exists in the varying period of sunspot revolution about the sun's axis, the period of revolution being a function of the latitude of the spot. The empirical law that has been discovered can doubtless be rationalized, for the sunspots (being electromagnets) owe their revolution not only to the sun of which they are a part, but to the electromagnetic field of the sun which must increase in force toward the sun's poles. Likewise the migration of the sunspots to lower latitudes is a result of their propulsion by the sun's magnetic field.

Oscillation Factor.—Since sunspots are generated by planets, as will be shown, and since planets vary periodically in their sunspot effects, and since planets differ as to their respective sunspot generating power, it follows that there must have been a periodic variation both in the number of sunspots and in their average latitude. This, then, introduces what may be termed an oscillation factor that affects the period of revolution of the planets that were generated by the sundust emitted from sunspots. Study discloses that this oscillation factor also follows a geometric series law, of which more will be said later.

Periodicity Chart.—Fig. 1 shows in graphic form the law of planet periodicities, the product of the abscissa by the ordinate giving the orbital period of each planet. The abscissas are shown as a geometric series in which the multiple is 2. The orbital period of each planet divided by its abscissa gives its ordinate or oscillation factor. The curve thus found from Mercury to Neptune was extended beyond Neptune by plotting the positions of 69 comets, which are indicated by dots, and then drawing a median line from *A* to *N*. It was assumed that the points of intersection of this curve with the ordinates *A* to *N* indicate the positions of undiscovered planets on the chart, whose names are designated as *A*, *B*, *C*, etc. The chart (drawn on a larger scale) indicates that planet *A* has an orbital period of $1.14 \times 256 = 291.84$ years. It was found that Lowell had predicted a planet of about 290-year period, and that Flammarion had predicted one of 300-year period. As will be shown later, planet *A* has produced sunspot maxima every 290 years and its orbital period is 295 years.

At the beginning of the curve in Fig. 1 is shown the sun's period of rotation. Then comes Vulcan, whose period was first calculated and later found to be almost exactly in accord with certain sunspot maxima.

A Geometric Series.—Study of the curve from *A* to *K* disclosed that if the ordinate of *K* is subtracted from each of the preceding ordinates, the remainders form a geometric series in which each number is double the predecessor. Although the median curve from *A* to *K* was drawn by eye, its ordinates fit very closely the geometric series just given. When later conclusive evidence was obtained as to the existence of planets *A, B, C, D, E, H, M, N, P, Q,* no doubt remained as to the law of geometric series both for the ordinates and for the abscissas of the curve in Fig. 1.

The oscillation factor (or ordinate) for planets *A* to *M* is given by the formula:

$$(1)\quad f = 0.56 + (.05 \times 1.25^{n-1})$$

n is the serial number of the planet by counting backward from *M* to *A*, calling planet $L=1$, $K=2$, $J=3$, etc.

Regarding the oscillation factors of the other planets, discussion is reserved for another article.

Law of Planetary Rotation.—The heads of comets contract as they near perihelion, indicating the effect of increased electromagnetic force resulting from the liberation of more electrons under the stronger radiations from the sun. Such contraction would necessarily be accompanied by increased rotative velocity. Similiarly the embryonic planet must attain a rotative velocity that is a function of the electromagnetic forces acting upon it. Since the number of lines of electric force that a planet cuts is a function of its orbital velocity (v) and the velocity with which the generating sunspots revolve about the sun's axis, which finds measurement in the oscillation factor (f), a formula for the period of planet rotation (p) should be a function of f and v. As a matter of fact, as shown in Table IV, the following formula gives fairly close results for all the planets whose rotative periods are known:

$$(2)\quad p = 2.86\, f\, v^{3/4}.$$

p=period of rotation, hrs.

f=oscillation factor.

v=orbital velocity, miles per sec.

Using this formula, assuming f to be constant, and introducing the law of diameter variation with distance, the Leavitt-Shapley law of absolute magnitude of the variable stars is readily deduced. This leads to the very important inference that the entire stellar system was probably generated by electromagnetic whirls, very much as the solar system was generated.

The Law of Sunspot Periodicity.—The electromagnetic whirl theory indicates that when the magnetic axis of a planet points most directly toward the sun, the greatest number of sunspots will be produced. Taking the Earth as a typical planet, it undoubtedly has two major magnetic axes: First, the one due to the rotation of the earth on its axis; and, second, the one due to the westward air current at altitudes of 20 miles and more. At high altitudes there is an eastward moving shell of highly ionized air that encircles the globe. It creates two whirls, one centering near the south pole, which is an ascending or cyclonic whirl, and one centering near the north pole which is a descending or anticyclonic whirl. This upper current of negatively charged air generates the upper magnetic field whose poles are slowly rotating westward around the axial poles of the globe. A similar magnetic field doubtless exists in the sun's upper atmosphere, for Hale has discovered that the sun's magnetic axis is also inclined and that its poles are slowly rotating. Since the number of free electrons is an inverse function of pressure, the ionization of the air increases rapidly with altitude. Consequently the electromagnetic field caused by the giant air-whirl must be very powerful. If we assume that these two magnetic axes do not coincide, and that the poles of the giant air-whirl rotate slowly westward, then it becomes evident that the maximum number of sunspots caused by the Earth will occur at intervals of less than 12 mos. By studying a curve of daily sunspots the writer found a sunspot period of 10.76 mos., which was provisionally assigned to the Earth. The well known so-called 11 yr.

sunspot period was assigned to Jupiter. It was found to be 11.207 yrs., whereas Jupiter's orbital period is 11.86 yrs. Similarly sunspot cycles were found and assigned to each of the other planets. Before the task was completed it became evident that the spread between a planet's period of revolution and the sunspot period assigned to the planet is greater the greater its orbital velocity. This led to the discovery that the following formula fits very closely the sunspot period assigned to each planet:

(3) $t=T\ (1-0.007\ v)$.

t=sunspot period due to a planet.

T=orbital period of the planet.

v=orbital velocity, miles per sec.

Table I shows how closely this formula fits the facts.

The Effect of Mars.—Study of the maximum number of sunspots corresponding to the different planets disclosed that Mars, although much smaller and farther from the sun than Venus and Earth, produces more sunspots. But this is what the electromagnetic theory might lead us to expect, for the axis of Mars is much more inclined than theirs, and therefore points more directly toward the sun. Axial inclination also explains why both Uranus and Neptune produce greater sunspot effects than Jupiter. Neptune's effects are about the same as those of Uranus; and Saturn's effects are much smaller, which is to be expected because its axis is but slightly inclined.

Since the Earth has two great magnetic fields, their combined effects are greater at intervals longer than 10.76 mos. The same is true of other planets, but this is a detail that need not be discussed now.

Table II shows the sunspot period assigned to each planet, and one of its relatively recent peak periods.

Table III shows sunspot peak years since 1615 A. D., and the peak periods of Jupiter, Uranus and Neptune. Planet *A* caused the sunspot peak of 1778; planet *B* caused the peak of 1847.

The writer has located the effects of more than a score of comets. Schuster's three sunspot periods of 4.8, 8.4 and 13.5 yrs. are assignable to the comets of 1819 IV (Nov. 20), 1889 VI (Nov. 29) and 1885 IV (Sept. 11).

Sunspot Cycles and Tree Growth.—Douglass was the first to demonstrate that the 11-yr. sunspot cycle frequently causes a corresponding cycle in the radial growth of trees. Huntington has shown that climatic changes have corresponded with a grand swing of the curve of growth of sequoia trees. Using the tabulated growth data gathered by Douglass and Huntington, the writer has been able to determine the sunspot cycles assignable to all the planets from Jupiter to Neptune. Using the same data, the cycles of planets *A*, *B* and *C* were discovered, and that of *E* was indicated. Baron de Geer's annual clay-varve chart was next used to supplement and greatly extend this investigation.

Sunspot Cycles and Clay-Varves.—The annual layers of clay deposited in ancient glacial lakes and in fiords have served, as above stated, to disclose the sunspot cycles of many planets. For 50 years Baron de Geer has been measuring and counting these clay-varves until he has produced a varve chronology that runs back more than 18,000 yrs., constituting one of the most remarkable of scientific achievements. The 11-yr. sunspot cycle is to be seen repeatedly in his charts. The writer has found many other cycles, and by their aid has been able to ascertain the date of de Geer's "zero year." The method of fixing its date was as follows:

The sunspot period of Uranus is 81.15 and that of Neptune is 161.57 yrs. Two of Uranus' cycles differ from one of Neptune's by 0.73 yrs. Since their last sunspot peaks were in 1837 and 1870, or 33 yrs. apart, it follows that they would occur together in 33÷0.73=45 cycles of Neptune back from the year 1837. On the clay-varve chart there is a Uranus peak at —1185 and a Neptune peak at —1173, or 12 years apart. Adding the 12 to the 33

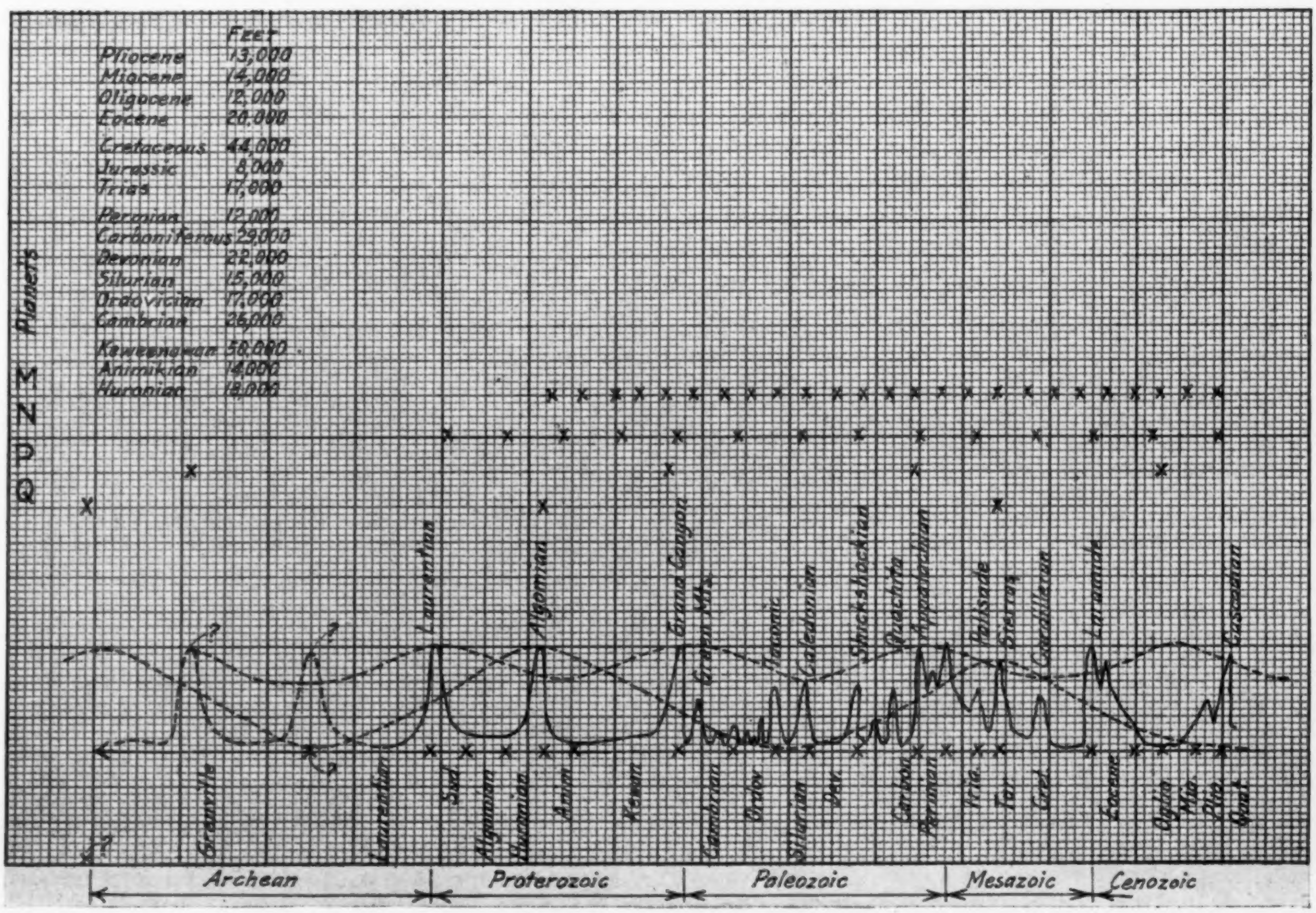


Fig. 2.—Eras, Periods and Upheavals and the Cycles of Planets M, N, P, and Q

yrs. we have 45, which divided by 0.73 gives 61, which is the number of Neptune cycles back at the year 1837 to the year —1173; hence 61×161.57=9856, thus making de Geer's year —1173 to be 9856—1837=8019 B. C., whence de Geer's zero year is 8019—1173=6846 B. C. There was a recent gap in the clay-varve series that de Geer had been compelled to estimate, and he had estimated that his zero year was about 6800 B. C., which he believed was within one or two centuries of the correct date. It will be seen that he missed it by only 46 years.

Using the sunspot period of planet *A*, which is 289.97 yrs., the writer secured the very same date for de Geer's zero year, namely, 6846 B. C., so there is no doubt as to its correctness.

The method of "triangulating" backward in the time scale, can doubtless be used to determine the exact age of any series of clay-varves, no matter how ancient. Since clay-varves exist at the beginning of the Huronian period, it will be feasible to carry an accurate chronology back for fully 15,000,000 yrs. of geological history.

Sunspot Cycles and Geological Strata.—Noting the frequent recurrence of a thickness of sedimentary rock of about 12,000 to 15,000 ft. in different geological periods, the writer inferred that the length of those periods might have been determined by a planet of very long orbital period. Starting with this clue, it was comparatively easy to develop a theory of stratification that fits the facts remarkably well. In very brief outline, it is as follows:

Fig. 2 is a chart reduced to one-quarter the scale of the original chart, and therefore not as satisfactory for purposes of proof; but the reader can readily plot a chart to a larger scale. In the chart the tabulated strata thickness of 16 periods is taken from Brooks' "Climate Through the Ages," p. 423. It will be noted that 6 of the 16 periods have a thickness that approximates 13,000 ft. Reed (The Varved Clays at Little Ferry, N. J.) states that the 2,500 annual clay-varves measured by him at Little Ferry have an average thickness of about 3/16 in., although the range is 1/16 to 1 in. Based on this average a foot of clay indicates 64 yrs. While there is a wide range of clay deposited between extreme years, it may be assumed that for a grand cycle of, say, half a million years, there would be a rather constant rate of erosion over great areas. Since the total thickness of sedimentary rock deposited in any geological period constitutes an integration of innumerable oscillations in rainfall, slope, temperature, etc., it is a fair presumption that such thicknesses form the best criteria of the time involved in the deposition of the strata. And until the recent use of the uranium-lead formula, this was the commonly accepted criterion, modified only by the use of "judgment." The uranium-lead formula gives results so widely differing from all others that it is open to the gravest doubt. Moreover it starts with assumptions that are unsupported by any facts.

Rate of Formation.—As a first approximation, if we assume that each foot of rock represents about 60 yrs. when taken over an entire period, we find that for a layer 13,000 ft. thick it gives a period of 780,000 yrs. The planet nearest to this period is planet *M* (Fig. 1) with an orbital period of about 587,000 yrs., its sunspot period being but very slightly (0.15 per cent) less, according to Eq. 3.

Since the Animikian period has strata thickness totaling 14,000 ft., which is just the same as that of the Pliocene, and since there are 286,000 ft. of rock between the beginnings of those two periods we have 21 cycles of planet M, each measured by 12,860 ft. of rock. But 586,000÷12,860=45.57 ft. of rock per annum. This was the second approximation in the problem of determining the chronology of the geological periods. Upon plotting this distance on a chart to a scale 4 times that of Fig. 2, and after locating the effects of another planet, *N*, in similar fashion, the value of planet *M* was slightly modified, making it 12,880 ft. of rock covering a period of 586,000 yrs., or 45.6 yrs. per ft. of rock.

Incidentally this time scale is about half as long per foot of rock as one that has been used by many geologists who have based sedimentary rock ages on present rates of erosion. But de Geer proved conclusively, by his clay-varves, that the age of the Niagara Falls gorge is only 40 per cent of the shortest age assigned to it by present rates of erosion, so our results are in general accord with his as to the lesser rate of present-day erosion. It should be remembered that the average slope of the ground surfaces was undoubtedly greater than at present, and that even a slight increase in slope greatly accelerates the velocity and erosive power of water.

The small crosses on the chart, Fig. 2, opposite planets *M* and *N*, indicate the dates of the peak affects of those planets on sunspots and on rainfall. The writer infers that even in the case of snowfall, during ice-age periods, the greatest erosion followed the winters of greatest snowfall.

The periods of planets *P* and *Q* (Fig. 2 and Table II) were determined by the periods of great continental uplifts. The Cascadian period occurs in a valley of the sunspot curve caused by planet *Q*, but the same is true of the Taconic and Caledonian uplifts. This anomaly is explained by the fact that the polarity of sunspots often changes at about the time of a sunspot minimum. A change in sunspot polarity produces corresponding changes on the earth.

The planet *M* has an orbital period of 587,000 yrs., which is only 19 per cent in excess of the 494,000 yr. period of a planet whose existence Pickering predicted. Pickering's method consists in finding the "mean argument" of aphelia of a group of planets (Annuals of Astr. Obs. of Harvard, Vol. 61, p. 166, yr. 1911). Pickering predicted a planet of 26,000-yr. period, which corresponds roughly with that of planet *H* (22,180 yrs.) and he predicted a planet of 13,038-yr. period, which corresponds roughly with that of planet *G* (11,600 yrs.). He made several other predictions, and all but the first one just named range from 10 to 30 per cent above the true periods. This indicates that most of the comets have lost velocity since they were generated.

Fourteen Giant Whirls on the Earth.—Sunspots have minor maxima once every rotation of the sun on its axis, or an average of about every 27.2 days as viewed from the earth. Also a daily sunspot curve shows other periods of about ⅛, ¼ and ½ of 27.2 days. This indicates that sunspots are more numerous along certain meridians. This phenomenon resembles the geometric figures that small floating magnets form under the influence of a powerful magnetic field. Hence sunspots, which are magnets, probably tend to assume a geometric grouping, under the influence of the sun's magnetic field and their own fields. Incidentally this may explain the arrangement of the "centers" on Mars from which the "canals" radiate to other "centers"; also the grouping of "craters" on our moon.

Such geometric groups led to a search for similar groupings of whirls in our atmosphere, several of which were quickly found on charts of the movements of clouds at elevations of 5 to 7 miles. When the centers of those whirls were plotted on a large map, it became apparent that they were also centers of similar whirls that had existed in the molten matter of the earth. Fourteen such centers were located, one about 8 deg. from each of the poles, six near the equator (three in each hemisphere), three near the arctic and three near the antarctic circles. Table V gives the approximate latitude and longitude of the center of 12 of these giant whirls, and their direction of rotation.

These 14 giant cyclonic air whirls ascend to levels somewhat above the level of the cumulus clouds, and there bend over, descending as anticyclonic whirls. These 14 anticyclonic centers at the earth's surface lie to the west of the corresponding cyclonic centers and in much higher latitudes. There is a periodic shifting of these 14 anticyclonic centers, the shift being to higher latitudes at times of greater relative intensity of sunspots of south polarity.

A study of the topography around each of these 14 centers at once reveals the fact that although the centers have remained practically stationary since the dawn of geological time, the whirls about these centers have varied in diameter, and that the whirls have been annular belts that were relatively narrow, belts of land elevation alternating with belts of depression.

What the Map Shows.—Only one map, Fig. 3, is here given to illustrate these whirls; and it is not the best map for the purpose of showing the truly remarkably circular topographical features of the globe. If the reader will locate center *A* near Timbuktu, Africa, he will find that the north western coast of Africa lies on a circle about that center for half the diameter of the circle. Similarly as to north western coast of South America about center *D*. Similarly as to the south eastern coast of Australia about center *E*. Another center, *B*, is noteworthy for the remarkable circular chain of islands (Sumatra, Java, etc.) about it; center *B* is in the Philippine Islands.

Although maps having the meridians drawn in straight lines, that converge toward the poles, serve fairly well for study of these 14 giant whirls, an 8-in. globe will be found much more satisfactory.

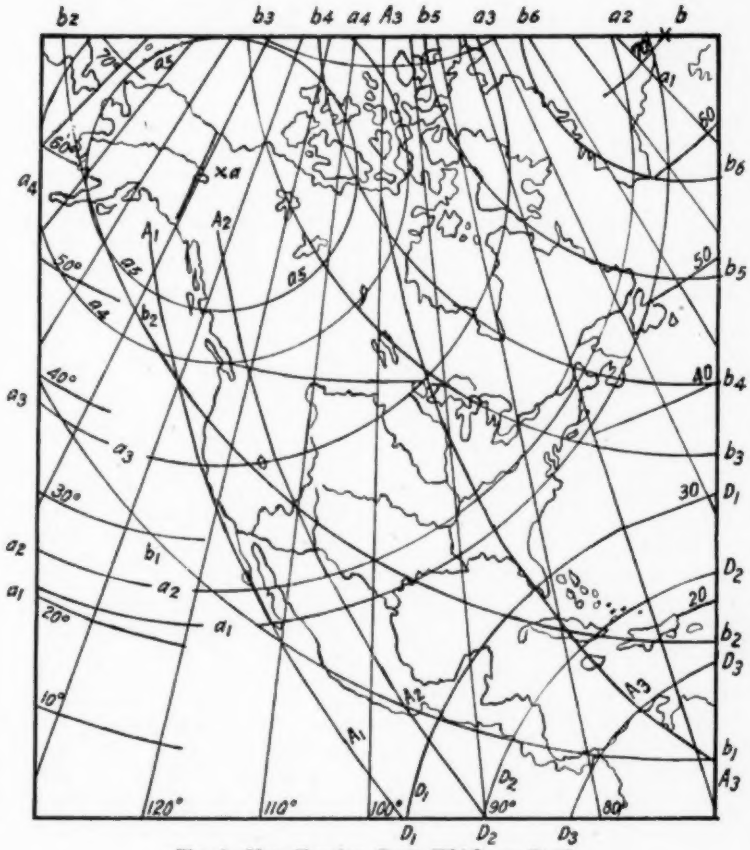


Fig. 3—Map Showing Great Whirls on Earth

Fig. 3 shows two whirl centers, *a* and *b*, about which whirls *a1* to *a5* and *b1* to *b6* have been drawn. Other whirls about centers *A* and *D* are shown. Whirl *A2*, for example, marks the backbone of the Rocky Mountains. About midway between whirls *a1* and *a2* lie the Alleghenies and the Appalachian Mountains. Contrast those two whirls of land elevation with the great whirl of depression, *b3*, which sweeps through the Great Lakes and the string of large lakes in Canada. This same whirl of depression passes through the centers of the Mediterranean and the Black Seas.

Even relatively small depressions (or elevations) frequently lie in series on these giant whirls. Note, for example, San Francisco Bay, Great Salt Lake, and Lake of the Woods, all on whirl *a3*.

Where two whirls of elevation intersect, an exceptionally great elevation frequently occurs; and a similar strengthening of effect often occurs where two whirls of depression intersect. This indicates that like whirls reinforce one another, whereas unlike whirls tend to nullify one another.

An Effect of the Planets.—It is evident that the belts of whirling molten matter rose or fell, depending upon their polarity, that is the direction of rotation, acting under the influence of the electromagnetism of the earth itself, of the giant air whirl whose axis terminates near the poles and of the sunspots and sun. That these giant whirls vary in intensity, and therefore in diameter, under the influence of sunspots, is hardly to be doubted. If then the sunspots come in cycles caused by the planets, it follows that the great planets *M*, *N*, *P* and *Q* have been the cause of repeated periodic rise and fall of land along certain belts of the earth. Incidentally this explains the great outflows of lava at about the beginning of geological periods and eras. It also explains the relative permanence of the elevated and depressed regions.

Since the giant whirl whose axis lies near the poles, has opposite polarity at the two poles, we should expect to find a general elevation of land at one end and a depression at the other. This is exactly what we find—a great antarctic continent and a great arctic sea. Incidentally the exceptionally low barometer (an inch below average) that exists within the arctic circle finds complete explanation by the electromagnetic whirl theory. Many other barometric riddles are readily answered by this theory, but space forbids discussion of them now.

The Earth's Interior.—Although most geologists have abandoned the old theory that the interior of the earth is still molten, it seems to the writer that the old theory is sound. Otherwise a change of land elevation of 1,000 ft. since the last ice age (only 8,800 yrs. ago, according to de Geer's unimpeachable clay-varves) is not explainable on any hypothesis that fits well with other established facts. Incidentally it was not relief from the weight of the ice cap, but electromagnetic propulsion that caused these land elevation changes. In fact it is the very same electromagnetic motion of the fluid interior that probably explains the well known periodicity of earthquakes and volcanic eruptions. Even the small 11-yr. effect of Jupiter's sunspots has a marked relation to earthquake frequency.

Numerous Other Whirls on the Globe.—Since the lunar "craters" are probably solidified electromagnetic whirls of molten matter, and since there are a great many of them, it is a natural inference that numerous whirls existed in the molten earth. Even casual inspection discloses many. One evidently caused the Lesser Antilles, and two others not far away produced the reversed curve that forms the Isthmus of Panama. The Florida Keys were similarly formed, and so was the Gulf of Mexico from New Orleans to Yucatan. The Alaska Peninsula and the Aleutian Islands lie on the arc of a circle; so do Cape Horn and the Falkland Islands.

The iron deposits of the Great Lakes lie mostly along circles whose center is about 50 miles west of Milwaukee. One of these same whirls outlines also the western edge of the Illinois coal field. It is noteworthy that five of the six main coal fields of Texas lie close to a circle whose center is the same one that was above referred to as the center of the Gulf of Mexico. Both contours and mineral zones are so frequently found to lie along circles that

Table I—Theoretical and Actual Sunspot Cycles Attributable to 8 Planets

	Cycle		Per cent
	Theoretical	Actual	Difference
Mercury	69.65 days	68.64 days	+1.5
Venus	190.7 days	201.5 days	—5.0
Earth	10.44 mos.	10.76 mos.	—3.1
Mars	20.21 mos.	19.50 mos.	+3.5
Jupiter	11.19 yrs.	11.21 yrs.	—0.2
Saturn	28.24 yrs.	27.72 yrs.	+1.9
Uranus	81.35 yrs.	81.15 yrs.	+0.3
Neptune	160.97 yrs.	161.57 yrs.	—0.4

Note: The "theoretical period" was deduced by the formula $t=T\ (1-.007\ v)$, in which $t=$ sunspot period, $T=$orbital period, $v=$orbital velocity in miles per sec.

this part of the theory discloses strong prospect of its immediate application in the search for coal, oil, iron ore, etc.

The ocean "deeps" were probably whirls of depression, and their resemblance to the circular "oceans" on the moon is thus explained. The "craters" on the moon were probably small whirls of molten matter.

Sunspots and the Magnetic Needle.—Since there are probably several powerful magnetic whirls in the earth, if it is still fluid inside, we should expect to find a rather complex behavior of the magnetic needle, which is the case. The astronomer Halley inferred the existence of two north and two south poles, and he explained them by an hypothesis of two rotating magnetic spherical shells within the earth. Like many another rejected theory, it may be revived and found to be useful. We have only to substitute a "shell" of highly ionized air for one of his earth "shells," to see that Halley's hypothesis may be essentially correct. If we add thereto some of the 12 other giant whirls, and probably some of the smaller whirls, it should be feasible to derive a very complete theory of earth magnetism in so far as it affects the magnetic needle. Even such variations as those that occur daily seem to fall into line with the theory; for the rays of the sun, particularly ultra-violet rays, ionize the air, and thus produce daily variations in the intensity of the electro-magnetism.

Whether the sunspots act directly on the earth, or indirectly through the change in ultra-violet radiation, it is certain that the magnetic needle shows periodicities corresponding with sunspot periodicities. The same holds true as to radio receptivity.

Sunspots and Weather.—No one can read carefully even a small part of the literature on sunspots without seeing that weather is, at least to some extent, influenced by sunspots. However, there are so many exceptions to the rule that rainfall varies with sunspot activity that not a few investigators doubt whether prognostications of weather, based upon sunspot activity, can ever become trustworthy. Remembering that if even but one physical variable remains unknown, no universally applicable law is likely to be discovered, an investigator should hesitate in predicting the impossibility of long distance weather forecasts. That there have been several unsuspected variables in this problem is evident from what has preceded. For example, it now appears that there are 14 giant whirls on the earth, and that their size is variable and that the direction of whirl of some of them may change periodically. This explains why sunspots may cause cyclonic storms in one belt of the earth, while at the same time causing dry weather in a nearby belt. It also explains the migration of certain storm belts to higher latitudes during periods of sunspot peaks.

Hale discovered that sunspots usually travel in pairs, and are of opposite polarity. Also he found that the leaders of the pairs are the most powerful, and that the leaders are usually of opposite polarity in the two hemispheres, yet only one meteorologist, Father Jerome S. Ricard, has put this fact to practical use, so far as the writer knows.

Polarity of Sunspots.—The writer finds that it is not the number of sunspots that determines the amount of rainfall, but that it is the preponderance of sunspots of one polarity over those of the opposite polarity, the preponderant polarity rotating in the same direction as the rotation of the cyclonic storms on the earth. This fact, taken with Hale's discovery of periodic reversal of polarities (i. e., direction of rotation), explains many of the anomalies of weather. Similarly it explains such anomalies of climate as were mentioned when discussing planet Q.

Of course the number of sunspots is only a rough measure of their magnetic effects, so that future investigations will be needed to determine the functional relation between number of spots and magnetic effects on the earth. In addition to which there is still another factor that the writer has not seen mentioned, namely, the direction of the axis of a sunspot relative to the earth.

Sunspots of south-polarity cause a liberation of electrons and a consequently increased electrification of the air. This increases the intensity of all cyclonic air whirls, with consequent lowering of barometric pressure and increased rainfall within the cyclonic areas. That the sunspots of south polarity rotate clockwise is indicated by the fact that when the south pole of the sun points most nearly toward the earth (Mar. 8) there is an increase of atmospheric electrification on the earth; and since the sun rotates clockwise when viewed from the south (anti-clockwise when viewed from the north), it follows from the electromagnetic theory, that a clockwise rotation causes greater electrification of the air. Since barometric pressure falls where such electrification increases, it follows that cyclonic activity increases and is the cause of the reduced air pressure. With reduced cyclonic activity the 14 giant anticyclones associated with the 14 giant cyclones subside in intensity, and rain storms then become more prevalent in the 14 anticyclonic areas.

The leader of a pair of bipolar sunspots is the cyclonic sunspot, and is the more powerful of the two in its electromagnetic effect. Hence in speaking of the polarity of sunspots, it is the polarity of the leaders that is commonly meant. At the present time (1928) the sunspots in the southern hemisphere have a south polarity and an inferred clockwise rotation. This will continue until about 1933 when the new cycle of southern sunspots will begin to have a north-polarity, according to Hale's law of reversal of polarity.

The relative number of sunspots in the sun's two hemispheres changes periodically. The writer has found that these periods are determined by the positions of the more powerfully magnetic planets, notably Neptune and Uranus, with reference to the plane of the sun's equator. When Neptune, for example, is north of the sun's equatorial plane, then it generates more sunspots in the sun's southern hemisphere than in its northern hemisphere. In general, a planet generates the most sunspots on the area of the sun most remote from the planet. Combining this principle with that of Hale relative to the periodic reversal of sunspot polarity, it becomes feasible to ascertain the periods during which the maximum electrification and minimum barometric pressure are produced in the earth's air.

There has long been observed a tendency for a 5.6 yr. rainfall cycle to occur in areas where the 11.2 cycle occurs. This is now explanable. At

Table II—Sunspot Cycles Attributable to 19 Planets

Planet	Series Number	Length of Cycle	Date of Sunspot Peak
Vulcan	1	29.49 days	Nov. 25, 1927
Mercury	2	68.64 days	Aug. 18, 1927
Venus	3	201.5 days	May 25, 1927
Earth	4	10.76 mos.	Sept. 15, 1927
Mars	5	19.50 mos	Jan. 18, 1927
Jupiter	8	11.21 yrs.	Aug. 12, 1917
Saturn	9	27.72 yrs.	Aug. 30, 1924
Uranus	10	81.15 yrs.	July, 1870
Neptune	11	161.57 yrs.	Jan., 1837
A	12	289.97 yrs.	May, 1778
B	13	512 yrs.	Oct., 1847
C	14	951 yrs.	1019
D	15	1,835 yrs.	1356
E	16	3,213 yrs.	420 B. C.
H	19	22,180 yrs.	7,919 B. C.
M	24	586,000 yrs.	293,000 B. C.
N	25	1,278,000 yrs.	521,000 B. C.
P	27	5,113,000 yrs.	1,524,000 B. C.
Q	28	9,390,000 yrs.	5,355,000 B. C.

Table III—Dates of 28 Sunspot Maxima and the Sunspot Periods of 3 Planets

Actual Sunspot Peak Year	Smoothed Curve Peak Year	Jupiter Period (11.21 yr.) Year	Uranus Period (81.15 yr.) Year	Neptune Period (161.57 yr.) Year
1615		1614.9		
1626		1626.1	1627.9	
1639		1637.4		
1649		1648.6		
1660		1659.8		
1675		1671.0		1675.5
1685		1682.2		
1693		1693.4		
1705		1704.6	1709.1	
1718.2		1715.8		
1727.5		1727.0		
1738.7		1738.2		
1749.9	1750.3	1749.5		
1761.4	1761.5	1760.7		
1769.7	1769.7	1771.9		
1778.4	1778.4	1783.1		
1787.9	1788.1	1794.3	1789.3	
1804.9	1805.2	1805.5		
1817.3	1816.4	1816.7		
1830.3	1829.9	1827.9		
1836.9	1837.2	1839.1		1837.1
1847.8	1848.1	1850.3		
1860.5	1860.1	1861.6		
1870.4	1870.6	1872.8	1870.5	
1882.3	1883.9	1884.0		
1893.6	1894.1	1895.2		
1907.2	1906.4	1906.4		
1917.6	1917.6	1917.6		
	1928.8(?)	1928.8		
	1940.0(?)	1940.0		
	1951.7(?)	1951.2	1951.7	

Note: Daily sunspot numbers are available since 1748, also monthly and yearly averages. Prior to that only the years of maximum and minimum sunspot numbers are available, and those back only to 1610.

such intermediate periods of increased rainfall during a minimum number of sunspots, sunspots of south-polarity predominate in marked degree over those of north-polarity.

Failure to realize that sunspots of south-polarity are the cause of barometric lows, has been at the bottom of much of the confusion relative to the relation between sunspots and weather. Coupled with confusion on this matter has been the confusion arising from failure to see that there are 14 giant non-migratory cyclones with their consequent 14 anticyclones.

As will be indicated later, the axis of a sunspot ordinarily is not radial with the sun, but it points backward in the leading sunspot of a pair, and forward in the following sunspot. This explains why sunspots produce their greatest effects when near the edges of the sun. It explains several other phenomena of a "lagging" nature.

U-Shaped Whirls.—Any whirling gas or liquid that is also advancing tends to bend. If it bends backward sufficiently an ascending cyclone descends as an anticyclone, forming an inverted U. Then if it breaks at the bend, there appears to be two independent whirls turning in opposite directions. This is the writer's explanation of the pairs of sunspots of opposite polarity. The alternation of low and high barometric centers that travel across any continent from west to east are similarly explainable. They are not only rotated electrically but propelled electrically eastward and toward the equator, as are sunspots. Incidentally, Clayton's law of cyclonic storm migration finds explanation by this theory. The more powerful leader of a pair, the cyclone, tows the anticyclone after it.

Table IV—Axial Rotation Periods of 6 Planets, Actual and by Formula $p=2.86fv^{3/4}$

	v	f	p, hrs.	Actual, hrs.	Difference
Earth	18.52	1.00	25.4	24.0	+ 6%
Mars	15.00	0.94	20.6	26.6	—22
Jupiter	8.12	0.74	10.2	9.9	+ 3
Saturn	6.00	0.92	10.1	10.2	— 1
Uranus	4.24	1.31	11.1	10.8	+ 3
Neptune	3.40	1.27	9.1	7.8	+16

In a whirl belt or zone of rising air, such as one of the 14 giants above named, there develop small whirls, which ascend and bend over. The rising warm air tends to lose its moisture by precipitation; and, becoming cold, descends as dry air in an anticyclone. It is this descent of anticyclonic air that explains the lowering of temperature in storm belts. Where the cyclones and anticyclones are made sufficiently large and strong by intense sunspot activity, an ice-age develops. This explains the coincidence of ice-ages and great land upheavals, for both are the effects of a common cause.

Ocean Currents.—The electromagnetic whirl theory explains ocean currents better than does the prevalent theory that they are the effects of winds. While it is true that winds and ocean currents have much in common as to their general motion, study discloses many motions that differ to such an extent that the wind hypothesis of ocean propulsion seems to be insufficient. Let ocean currents be studied with respect to the 14 whirl centers, and they will be seen to find better explanation.

Convection Currents Inadequate.—Although meteorologists have usually regarded weather changes as being almost completely explainable as due to heat differences, there has been accumulating a mass of facts that have not found explanation in the convection theory. Huntington has stressed the fact that climatic changes are kin to weather changes. He has suggested the possibility of electric forces as causes of weather and climatic changes. But having only one fairly well established sunspot cycle, namely, the so-called 11-yr. cycle, and with no established theory of the cause even of that one cycle, it was not feasible for him to carry his hypothesis far. However, his books were of great help to the writer, for they contain many facts and relations between facts that became highly significant once a definite hypothesis had been framed. The same is true of many of the facts in Clayton's "World Weather" and in Brooks' "Climate Through the Ages."

Huntington's great conception of climatic changes as results of stellar influence was not correct in that he had in mind stars instead of planets. Yet such rational gropings after truth often are extremely suggestive guides to men who come later in search of the cause of things. All creative thinking is of that type. The slightest likeness between two phenomena may be the first clue to a great kinship.

Table V—Locations of the Centers of 12 Giant Whirls

Whirl Center	Latitude, Degs.	Longitude, Degs.	Direction of Whirl
A	18 N	4 W	Clockwise
a	64 N	136 W	Clockwise
B	16 N	121 E	Clockwise
b	68 N	22 W	Clockwise
C	8 N	180 W	Clockwise
c	64 N	76 E	Clockwise
D	2 S	67 W	Anti-clockwise
d	69 S	174 W	Anti-clockwise
E	29 S	144 E	Anti-clockwise
e	69 S	30 W	Anti-clockwise
F	9 S	140 W	Anti-clockwise
f	70 S	68 E	Anti-clockwise

The writer does not agree with those who insist upon complete proof of a theory before publication. Had Fitzgerald not suggested the hypothesis that matter contracts in the direction of its motion, Lorentz would never have deduced the contraction of electrons; and had this deduction not been made, there would have been no Einstein theory of relativity. After even one such episode in scientific history, no one should attempt to weigh the value of any embryonic scientific hypothesis, and find it worthless merely because it is but an embryo.

Sunspots, Ice Ages and Evolution.—When Agassiz published his ice-age theory, Humboldt wrote to him saying: "Agassiz, you should stick to your fishes." Fortunately for geology Agassiz did not stick to his fishes, nor William Smith to his surveying compass, nor Hutton to his pills. The secrets of nature are not infrequently more evident to the amateur than to the expert; for the expert's eyes are often diverted from the truth by a long accepted theory that is false. False theory is as misleading as true theory is enlightening.

From the electromagnetic theory it is to be inferred that ice-ages have marked the apex of every geological era. It is no mere chance that each great ice-age has ushered in a host of new species, and has wiped an older host off the slate. The new living conditions caused by such great climatic changes have killed off those species that either could not accommodate themselves quickly enough or could not migrate far enough. Enforced migration, during the ice-ages, has led to the crossing of different strains of the same species which, as Burbank discovered, results in many extreme departures from type. This greatly accelerates evolution.

Man himself would still be unevolved were it not for ice-ages, and therefore for sunspot cycles, and therefore for planets as yet unseen. Although unseen, many planets make themselves evident by effects that are visible, just as is the case with atoms and electrons.

Planet *E*, whose sunspot period is 3,213 yr., was one of the causes of the last ice-age, which reached its apex 6846 B. C. Planet *E* also caused the cold, wet period that reached its apex 420 B. C. It is also responsible for

the drought period, whose extreme was about half its period or 1607 yrs. later, 1187 A. D. Since then there has been an upward trend in rainfall, affected, of course, by the sunspot cycles of the lesser planets.

Planet H, whose period is about 22,000 yr., cooperated with planet E, and both were aided by the great planet Q.

Climatic Changes.—As Huntington correctly inferred, climate shows periodic changes that are merely weather changes on a greater scale, both of intensity and duration. We may therefore expect ice-ages to come again, and, with their coming, to affect life on the earth as profoundly in the future as it has been affected in the past. But by study of past effects, guided by a correct theory, man will be able to forecast accurately the next ice-age, and thus will be able to prepare for it far in advance by moving to spots where genial climates will exist. Long before that event, electrical engineers will have learned to apply the whirl theory in countless ways, and will have discovered how to bend to man's service the vast magnetic whirls above and beneath the earth's surface. Geologists will have learned how to predict earthquakes and volcanic eruptions, and, what is vastly more important, will have discovered the laws that determine the location of mineralized belts. Astronomers will have reduced the forecasting of sunspot changes to an accuracy comparable with the forecasting of eclipses; and guided by such knowledge, meteorologists will have attained to almost equal precision in foretelling the weather far enough in advance to guide the farmer in his crop plans and the engineer in his location and design of hydraulic works.

Highway Accidents Largely Preventable

During every 24 hours of 1928 an estimated average of 2,360 persons are being killed or seriously injured on the streets and highways of the United States. The estimated economic loss for the first six months of 1928 was $350,000,000 exclusive of small property damage and insurance premiums. At the present rate of increase the "Grim Reaper" will exact a toll of 40,000 human lives in highway accidents during 1935. These figures were part of an analytical highway safety report issued today by the American Road Builders' Association.

During the first six months of 1928 the American Road Builders' Association estimates that 13,750 persons were killed and 412,500 seriously injured in highway accidents. The toll for 1927 was 26,618 killed and 798,700 seriously injured, a total of 825,318 casualties. At the present rate approximately 27,500 persons will be killed by the end of 1928.

What do these figures show? Do they indicate that the American people are becoming alarmingly careless at the wheel of an automobile or while walking upon the street? Do they mean that modern cars are too fast or too inefficient to be safely operated on our system of highways?

A careful analysis of highway accident statistics will show the latter to be largely untrue. The principal causes of highway accidents, it will be shown, are discourtesy and carelessness on the part of both drivers and pedestrians. The statistics prove the following points:

1st.—That the most important causes of highway accidents where motorists are principally at fault are in order of their importance — inattention, speeding, traffic law violation and intoxication. Of the 26,618 killed in 1927, motorists were at fault in 11,765 fatalities and all but 1,882 were attributed to the above causes.

2nd.—That the most important causes of highway accidents where motorists are principally at fault are: children playing in the street or crossing in violation of traffic law, adult jay-walking, inattention, and confusion. Of the 11,367 deaths caused principally by pedestrians in 1927, all but 1,250 were attributed to these causes.

3rd.—That adverse physical conditions such as wet streets, defective roads, poor lights and narrow streets, caused but 3,586 deaths.

4th.—That the human factor is responsible for 95 per cent of all accidents.

5th.—That the human factor which causes highway accidents is largely the result of certain definable physical conditions such as complex traffic laws, traffic congestion, discourtesy on the part of fellow motorists, carelessness on the part of fellow motorists, fatigue, physical incompetency, lack of confidence and the improper conduct of pedestrians.

6th.—That approximately 60 per cent of all fatalities are pedestrians.

7th.—That more than 30 per cent of all fatalities are children of school age.

8th.—That accidents involving pedestrians continue to climb in number much faster than accidents involving only motorists.

The American Road Builders' Association has collected much data related to the causes of highway accidents. The organization has used, in addition, much information already made available by other associations interested in the safety problems. The road organization has launched as a result of its studies, a national highway safety campaign based upon what it believes to be the fundamental principles of highway accident prevention. These principles are in brief:

1st.—That all cities and communities should undertake local campaigns to educate pedestrian traffic in the principles of courtesy and caution while on the public street or highway. The use of common sense is recommended in lieu of complex traffic rules.

2nd.—That all states should adopt a system of examination and licensing of motor vehicle drivers.

3rd.—That the adoption of the uniform codes of state and municipal traffic laws based on the report prepared by the National Conference on Street and Highway Safety is desirable.

4th.—That the education of drivers in the principles of courtesy and caution should be undertaken in all communities.

Combining Open and Tile Drains for Road Bed Drainage

An interesting instance of the deficiency of open side drains in the drainage of a road bed was cited by G. R. Marston, County Engineer of Norfolk County, Ont., in a paper presented at the 1928 convention of the County and Township Engineers of Ontario. We quote as follows:

"A few years ago I constructed a piece of road with open side drains, the grade being gravelled with about 8 in. of consolidated gravel. The bottom of the open drain was about 3 ft. below the surface of the completed road, and the road in question was built on a grade of about 0.5 per cent. After the break-up of winter the side drains were quite dry, having carried off all the freshet water, but the road bed went to pieces and there was water standing at the top of the road. Public opinion was conveyed to me through my patrolmen that there was not sufficient gravel on the road to carry the traffic, and consequently another coating of gravel was applied. The same result followed the next spring when the road broke up. I was requested to put more gravel on this road, but refused, as I considered it was useless. I made up my mind that some other method must be adopted to overcome this difficulty and I put in 400 ft. of 4-in. tile in herringbone fashion and gave the road an application of 2 in. of gravel. The road has since passed through two spring break-ups without any damage to the road bed. This again proves to me that the use of the open side drains is not sufficient in a number of places and that one must study each particular piece of road bed as regards the type of drainage that will be used."

Lowering End of Causeway on California Highway

How Job Was Accomplished Told in California Highways and Public Works

By C. E. BOVEY
District Maintenance Engineer, California Division of Highways

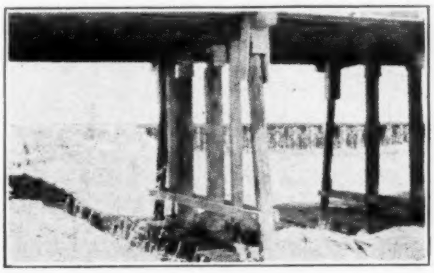
THE Yolo Causeway, situated in Yolo County, California, has on the west end 2,470 lin. ft. of wooden trestle, the grade line of which is 6 ft. higher than the paved highway connecting it. The run-off as constructed was very short and the vertical curve in the trestle itself is only 75 ft. in length, giving a sight distance of less than 500 lin. ft. On account of the fast traffic across and adjacent to the causeway, a great many accidents have occurred due to this short sight distance.

As on all wooden deck bridges topped with asphalt surface, moisture gathered during the night and in freezing weather turned to ice, creating a more hazardous condition during the night and early morning hours. As the wheel guard and guard rail on this trestle were of the old standard type, they proved insufficient to keep skidding machines from crashing through to the ground, some 18 ft. below. To correct this condition, it was decided to resurface the trestle with a non-skid layer of ¾-in. rock and asphalt and replace the old wheel guard and guard rail with a new and heavier type, the wheel guard to be constructed of 8-in. by 12-ft. timber placed on 3-ft. blocks, making it 15 ft. high, which is 1 in. higher than the concrete wheel guard on the main structure, which has always proven sufficient to keep machines from crashing through; the guard rail to be constructed of 8x8 posts and 6x6 railing securely bolted to the stringers and wheel guard.

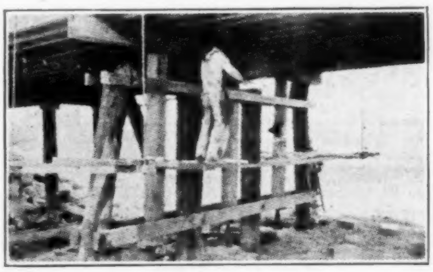
Increasing Sight Distance.—In addition to these corrections, it was decided to lower the last 19 bents of the wooden trestle in order to substitute a 400-ft. vertical curve in place of the 75-ft. one, thus increasing the sight distance of less than 500 ft. to over 1,500 lin. ft., thereby materially adding to the safety of the traveling public.

The bents were of the standard four-pile type, the two outer piles being on a batter.

Bids Too High.—It was decided to contract the lowering of the trestle and the placing of new wheel guard and guard rail, but the bids received were all entirely too high and were, therefore, rejected. Most of the bids were particularly high for the lowering item ranging from $1,000 to $3,808, while the engineer's estimate was $600. The highest bidder on the lowering of the trestle was the lowest bidder on the placing of the wheel guard and guard rail, and it was thought best by the district office, since the contractors were evidently worried about the lowering of the trestle, to have the lowering done by state forces and to readvertise for bids for the placing of the wheel guard and guard rail. Therefore, the lowering of the 19 bents was undertaken with the district maintenance forces, using a crew of four men under the leadership of Foreman D. G. Hasse, of Stockton.



Showing the Bents After Cut-Offs Have Been Made With 4x12 in. Shims in Place and Showing Part of the Scabs Holding Then in Place



Showing the Jacks in Place and the Crew Making the Cut-Offs. Note the Swinging Stage From Which the Men are Working

Used Jacks.—The cut-offs ranged from 1 in. to 2 ft. All the sway brace bolts and braces had to be removed first and then jacks placed under each bent separately, the cap raised just enough to take the weight off the piles while they were being cut off to the new grade.

The old drift bolts extended into the piles approximately 10 in. and in most cases were left intact.

Where the cut-off was over 12 in., the drift bolts were cut off at the cap for the batter piles, because of the change in the position of the drift bolt with respect to the pile.

In order to save cutting as many drift bolts as possible and the driving of new ones, the old drift bolts were forced into the pile below the cut-off by placing blocks between the deck and the cap directly over the top of the drift bolts. The weight of the deck forced the drift bolt into place without any difficulty. Where the drift bolts were removed, new ones were placed by boring through the deck and cap and driving them into place by use of a follower.

Staging.—A swinging stage was used entirely, the staging being suspended from the wheel guard. This proved far more economical than staging nailed to the piles or set-up on the ground.

It was planned to lower the deck not over 4 in. at a time, therefore, as soon as the cut-offs were made, 12 by 4 shims were placed between the top of the pile and cap and held firmly in place by 2x12 scabs nailed to the cap and piles. Where the cut-off was less than 4 in., the deck was lowered to position as soon as the cut-off was made. After all cut-offs were made, the deck was lowered 4 in. by removing the 4-in. shims, and this process continued until the entire deck was in place. Sway braces and drift bolts were then replaced and the tops of all piles were treated with creosote paint in order to make them conform with the original job.

The only difficulty encountered was caused by the springing of the piles. Many of them, after the cut-offs were made sprung as much as 3 ft. out of line and had to be pulled back into place and anchored, which raised the cost considerably.

Final Cost.—The final cost bore out the judgment of the district office, as the entire lowering was completed for slightly less than $550 as compared with the low bid of $1,000.

Some of the contractors, in bidding, figured on having house movers do the lowering by placing jacks under all of the 19 bents and lowering simultaneously. House movers, however, wanted approximately $1,200 to do the work in this manner, while our four-man maintenance crew handled the work very efficiently, doing an excellent job for only $550, by lowering each bent separately. Traffic was not interferred with in any way, and the traveling public was unaware that anything was being done to the structure.

New bids received for the placing of the wheel guard and guard rail justified the action of the district in reject-

ing the original bids and doing part of the work by force account. With the lowering feature eliminated, better prices were obtained for the placing of the guard rail and wheel guard. The lowest original bid was $12,559.60, while the lowest bid for the placing of the guard rail and wheel guard alone was $9,781.20, which, added to the cost of lowering, $550, makes the total cost of the job $10,331.20, effecting a total saving over the original low bid of $2,228.40.

Roadside Development

Abstract of Address Presented June 3 Before Northern Road Builders' Association of Michigan

By H. F. LARSON
County Engineer, Iron County, Michigan

We are spending large sums of money each year in the building and maintaining of roads. But what of what is alongside the road? If we have not the foresight to develop the land which is adjacent to the road way, why then we are merely providing a rapid means for getting in and out of the state and the tourist who will come up this way will just pass on and our good roads, as far as the tourist trade is concerned, are worthless. The people who live in the cities want to see trees, catch fish, etc., and what is adjacent to the roadside is what is going to attract and hold them here. If we have no forests, etc., people are not going to visit us. The legislature of Michigan has provided all the machinery necessary to the putting of our roadsides to work. This tourist trade is something which we must cater to and if we do not do it someone else will and derive the benefit.

Preservation of Roadside Timber.—One of the first things we should do is provide for wider rights of way and the preservation of roadside timber. We are now confronted with the problem of keeping our roads open the year round. In our timber areas you all know the snow removal problem is much easier than in the open country and if for no other reason we are justified in spending large sums of money for the preservation of this timber. Then, too, is it not much better to have a roadside which is green and well kept than one which has no vegetation and nothing but a lot of black charred logs and stumps?

In regard further to roadside development, we have been more destructive than conservative in the past. In the old days, clearing meant cutting every tree in sight on the right of way. We are trying to preserve all or as many trees as possible on our rights of way. Engineers are not yet as thoughtful as they might be in relocating or rebuilding of old roads. Often a slight alteration of the proposed alignment would miss a fine group of trees and preserve what would otherwise have to be cut.

The greatest evil in the forest sections of this State is the so-called "slashings," which are usually piled up along our rights of way. After roadside development and care, it is discouraging to have some jobber log the timber next to the right of way, leaving a mess in the spring. A couple of years later when young trees get a good start a forest fire accomplishes something that will take years to heal. The 1927 legislature did pass an act which makes it mandatory upon the land owners to clean up a strip 100 ft. in width adjacent to all rights of way. This will not only preserve the beauty of the roadsides but make it next to impossible for forest fires to start along a highway.

Parks Along Highways.—In order to stem some of this tourist trade, a system of state and county parks must be established along our highways. You counties who have done nothing along this line should recommend to your county board to buy just a small beauty spot, fix it up, keep it clean and I venture you will not be permitted to stop without acquiring more.

We have not been as careful in the past as we might have been in the work of weed and brush cutting along our highways. Nothing looks worse than a beautiful roadway and poorly kept roadsides. In order to preserve and encourage small trees which are trying to spring up along our roadsides, it might be a good plan not to cut brush and weeds outside of the ditch line until such a time when the young trees can be distinguished and permitted to grow without being annually cut down.

In conclusion, permit me to suggest that if our forest laws should be changed to a sound economic basis resulting in a harvest tax, our forest problem will not only be solved but our hunting and fishing will be preserved for posterity, because you can not have one without the other. Remember we are the first generation in this country to feel the pinch as far as timber and game is concerned and I believe I can safely say that had we been given the same conditions that our predecessors had seventy-five years ago, we would not have done things any differently than they did. But on the other hand, if forest fires could have been kept down, the land would have reforested itself and had we had the foresight to have selectively logged, the old belief among the early lumbermen that the industry would have lasted forever would have come true.

Without a doubt, old northern Michigan, a country of forests, deer, rushing waters and silent places, is dying. A new north will take its place. Its lakes will be surrounded by cottages, golf courses, resorts, hotels, etc., men and women in fine clothes will be seen promenading around. We can probably call this "development," for it will bring new people and new money to many and perhaps many will be glad. But the person who will want to go into the woods, set up a tent, watch the deer feeding along the shore of a lake, will feel different. If you will want real forest solitudes you will have to think about Canada, for you will have to move north with the frontier.

Extra Work or Bidding Contingency

A new problem for the highway contractor or the engineer has arisen in California. It is described as follows in California Highways:

"There are tears as well as smiles in the story of Jumbo, huge circus elephant, who died last month on the Hauser contract in Humboldt County.

"The trucks hauling the circus to which Jumbo was attached, while on the way from Humboldt to Del Norte County became mired in road under process of construction. Efforts to get the trucks out of the mud by their own power were unavailing.

"Jumbo was requisitioned into service. He pushed truck after truck out of the mud and from one hole to another until the circus parade was on its way again.

"Then Jumbo laid down on the road in a state of complete exhaustion. All efforts to rouse and revive the huge animal were unavailing.

"Finally the driver of the elephant went to his charge.

"'Time to show, Jumbo,' he said. Jumbo flopped his huge ears, and started to rise. 'Time to show, Jumbo,' said the driver again.

"True to the instincts of the showman, that whatever may happen, the show must proceed, Jumbo again tried to get up. But the effort was too much. The show, however, was safe. It was on its way, out of the mud. Jumbo sank back—dead.

"Then the Hauser forces buried the faithful elephant. The question now is as to whether the removal of the carcass of a dead elephant from right of way is properly a contingency that a contractor should anticipate in his bid, or should an extra work order cover the cost."

Pride in Your Work

When your project is completed you will be moved to some other work, but the road or bridge, which has been constructed under your charge, will remain as a standard by which you will be judged. Your work is important and is worthy of pride. Your pride in your work should not only cause you to do everything possible to secure the best quality of materials and workmanship, but should cause you to see that the appearance is equal to the quality. A large part of the judgment of a road by the public is based on appearance for the average man passing over a road knows very little of its quality. If it rides smoothly and looks well it is adjudged a good road.—From Arkansas State Highway Department Instructions to Resident Engineers.

Hudson River Highway Bridge to Span 3,500 Ft.

Interesting Facts About Great Structure Upon Which Work Has Been Started

THE Hudson River bridge, now under construction, is distinctly a bridge of the future. One hundred years hence bridges of this magnitude probably will be common practice where such great spans are required. This great highway bridge, which has a main suspension span of 3,500 ft. and which provides an initial 40-ft. roadway, with provision for two later 24-ft. roadways, and a lower deck to carry from two to six lines of rapid transit tracks or vehicular roadways, or a combination of both. This bridge has its New York approach between 178th St. and 179th St., in the Washington Heights residential district, and will terminate in a plaza beginning at Pinehurst Ave. On the New Jersey side the bridge approach is through the Palisades and Fort Lee, and will be extended to top several main highways.

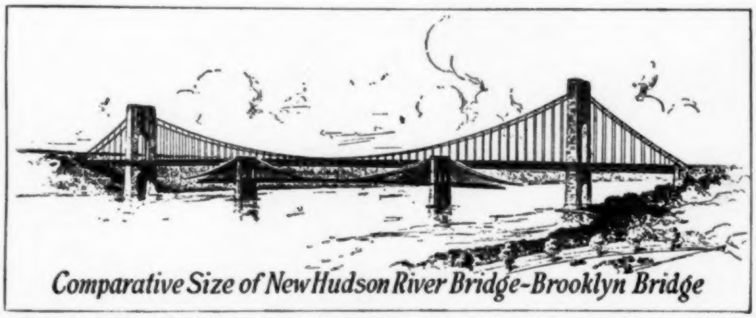


Fig. 1.—Drawing Showing Comparative Sizes of the New Hudson River Bridge and the Famous Brooklyn Bridge

Unlike the Philadelphia-Camden bridge, which will reach its maximum capacity within the next ten years, the Hudson River bridge will be increased in capacity as the demand requires, that is, the towers and main cables only are built originally for the full capacity. The additional roadways on the suspended structure will be built to meet the need as the demand increases. This means that when this bridge is opened to traffic in 1932, it will not have the beauty of the Brooklyn bridge, it will will be simply a steel skeleton with no indication of its finished beauty.

To explain this apparent disregard for the early appearance of the structure, it is necessary to consider the economic side of the proposition.

Owners.—The Port of New York Authority, created by compact between the States of New York and New Jersey for the purpose of development of the Port of New York, is authorized and empowered to construct, operate, maintain and own the Hudson River bridge. The Port of New York Authority must, therefore, consider the financial status of major importance, for they must issue bonds to cover the cost of the $60,000,000 bridge. The carrying charges on $60,000,000 of bridge bonds and the $10,000,000 advanced by the States of New York and New Jersey is approximately $3,000,000 per year.

To build the bridge for its maximum capacity would take eight years and cost $20,000,000 additional. You can readily see the cost of carrying charges over this period of time. The problem of the engineers of the Port of New York Authority was to build a bridge in the minimum amount of time to take care of the present requirements, and design same for future

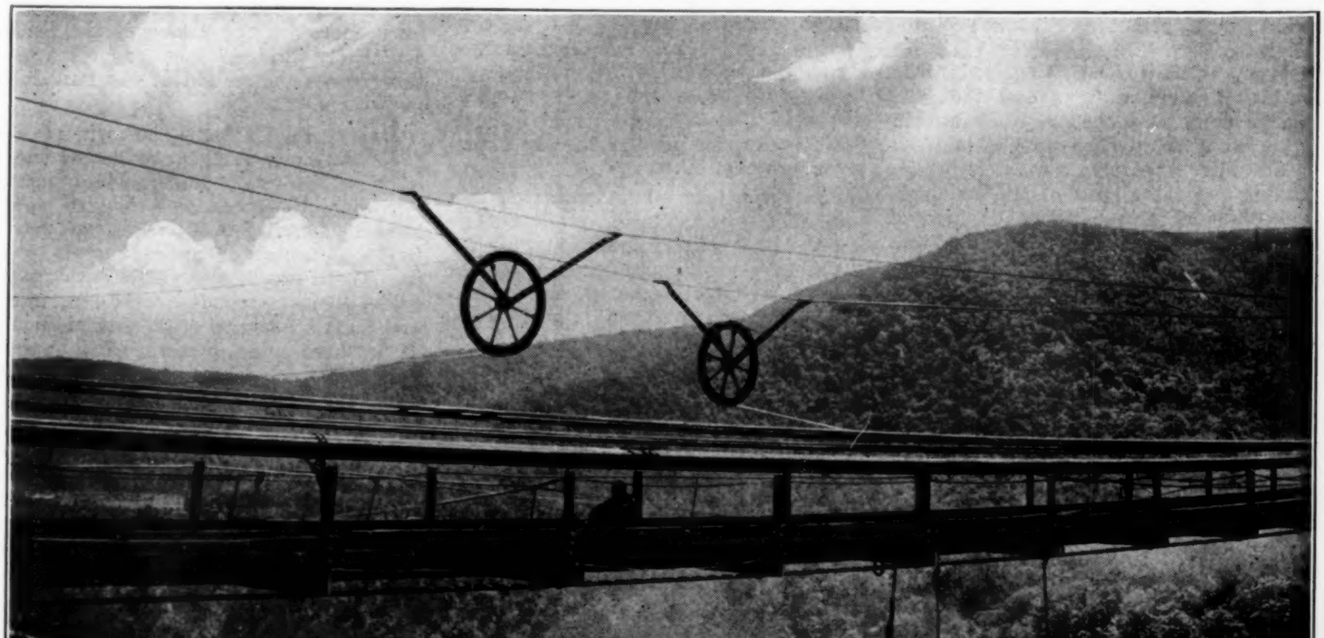


Fig. 2.—The Wheels Used in Constructing the Cables Passing at the Center of the Span. Note the Loop of Wire Over Each Wheel. The Workman Sitting Beneath the Partly Finished Cable Is the Flagman Waiting for These Wheels to Pass Over the Tower, After Which He Will Give Signals for the Adjustment of the Wires. This and Other Views Were Taken on a Recent Small Project, but Illustrate the Methods to Be Used on the Hudson River Bridge

Fig. 3.—Changing the Cable Cross-Section from Hexagon to Circular by Hydraulic Press or Clamp. The Hudson River Bridge Cables Are Twice the Diameter of This One

additions to take care of future requirements.

Rapid Construction Required.—The result of their study shows that the bridge must be opened to traffic within a period of four years, namely in 1932.

Consider what this means, a bridge having twice the span of the Philadelphia-Camden bridge, must be erected in the same period of time. It was considered that the Philadelphia-Camden bridge erection represented the maximum speed possible.

The bridge will doubtless be built within the time specified, as the contractors are subject to a penalty for delay beyond the specified time. The aggregate of this penalty is $6,000 per day.

Traffic Forecast.—The study of the estimated traffic for 1932 will give a fair idea of the importance of early completion.

The estimated volume of traffic across the Hudson River bridge in 1932 is as follows: 8,148,000 vehicles carrying 18,900,000 passengers; 500,000 buses; 1,500,000 pedestrians.

The gross revenue from tolls for the year 1932 is estimated to be in excess of $4,000,000.

The above gives a fair idea of loss in revenue if the bridge was originally built for full capacity requiring four years additional time. This, in connection with the high carrying charges, shows the wisdom of the engineers in building to meet the traffic requirements as they develop. It also shows the occasion for penalty in case of delayed erection.

Site Conditions.—It is estimated that the traffic over the initial roadway during the first year of operation will give sufficient revenue more than to cover the annual interest charge, administration, maintenance, and amortization. A careful survey of the Hudson River, at the bridge site, shows that for a with of 3,200 ft. across the river, rock bottom is 200 ft. below the surface of the water, and as a bridge of this magniture must be founded on solid rock, it was necessary to fix the span length at 3,500 ft. so as not to go beyond 100 ft. below the surface of the water to reach solid rock on which to rest the pier foundations for the New Jersey tower. The New York pier foundation is on solid rock located above the water line.

The two piers for the New Jersey tower are solid concrete and masonry, each one being 100 ft. long by 90 ft. wide, and extending from solid rock to 15 ft. above the water line, a height of over 100 ft. On these piers are located the two steel legs of the tower, rising to a height of nearly 600 ft. above the water. The Washington Monument could be placed within each tower leg.

A Large Steel Order.—There will be required approximately 80,000,000 lb. of structural steel for the towers of this bridge, over four times the weight of steel in the Philadelphia-Camden bridge towers. These towers must be built within 20 months from date, or only five months longer than it took for the erection of the Philadelphia-Camden towers.

At a future date the steel towers will be incased in concrete with masonry facing and will then rise to a height of 650 ft. above the water line. The dimensions of the tower top are approximately 40x180 ft.

Roadway Facilities. — The bridge, when first opened to traffic, will have one roadway 40 ft. wide and later two additional roadways, each 24 ft. wide will be added. When traffic is further increased, a lower deck will be added, and two to six lines of rapid transit tracks or vehicular roadways or a combination of both will be added.

What this means is best shown by the engineer estimate of traffic for 1950: 15,000,000 vehicles carrying 38,500,000 passengers, 1,000,000 buses, 3,000,000 pedestrians.

With this in mind let us consider that all this load must be carried by the main cables, a total of 168,000,000 lb., or 84,000 tons, as the suspended live and dead load on the main span of 3,500 ft. length. The suspended live and dead load on the main span of the Philadelphia-Camden bridge is 26,000 tons, therefore the cables of the Hudson River bridge must support over three times the weight of the Philadelphia-Camden bridge.

Making the Cables.—The main cables for this super-bridge are constructed of wires 3/16 in. in diameter laid parallel, side by side, and divided into strands, containing 434 wires, and having a diameter of approximately 4½ in. There are 64 strands in each main cable. These strands are laid parallel and form a hexagon cross section about 42 in. across the corners. This hexagon cross-section is then compacted by hydraulic presses to a circular cross-section about 36 in. in diameter.

The minimum ultimate strength of each wire is 6,800 lb. There are 26,474 wires in each main cable, therefore the ultimate strength of each main cable is 180,000,000 lb., and for the four main cables a total of 720,000,000 lb. strength.

The length of main cables from anchorage to anchorage is approximately 5,200 ft., therefore in the four main cables there is a total of 551,-200,000 ft. of wire.

The total weight of the four main cables is 57,000,000 lb., or 28,500 tons.

Erection of Cables.—Let us consider the erection of these main cables and

get an idea of the magnitude of this problem.

The first pair of main cables, weighing 12,450 tons, must be erected in a period of 15 months, and the second pair erected in a period of 12 months. The main cables of the Philadelphia-Camden bridge, having a total weight of 6,750 tons, was specified to be erected in a period of 18 months. The contractor must therefore erect more than twice as much wire in 5/6th of the time specified for the Philadelphia-Camden cables. This applies to the first pair of main cables. For the second pair the contractor must erect more than twice as much wire in 2/3rds of the time specified for the Philadelphia-Camden cables.

To give a better idea of the size, length and weight of the four main cables, total the weight of wire in the main cables of the Brooklyn, Williamsburgh, Manhattan, Philadelphia-Camden and Bear Mountain bridge, and it will be found that it adds up to 22,400 tons of wire. Add to this the weight of wire in the cables of the two new suspension bridges now being erected, one at Poughkeepsie, N. Y., and the other at Detroit, Mich., making a total of 27,800 tons of wire, and you still lack 700 tons of wire to equal the weight of wire in the Hudson River bridge.

Erection Methods.—These main cables are built in place, wire by wire, and the operation of constructing these cables will require the services of over 300 men for a period of two years.

To string and place each wire in the main cables requires a walkway a mile long and following the contour or curve of main cable throughout its length and situated about 3 ft. below the main cable. A walkway or footbridge, as it is called, is required for each main cable. To support these footbridges there is required over 200,000 ft. of 2⅞ in. diameter suspension bridge cable, sufficient material to make one of the two main cables of the Bear Mountain bridge. The erection of footbridges for this great bridge requires great precision of measurements and great daring of the constructon gang. These footbridges are temporary and must be removed after the completion of the building of the main cables, thus it is necessary to build and then dismantle a small bridge in the process of building the larger one.

An interesting phase of the footbridge design is due to the extreme grade or incline of footwalk between the tower and anchorage. This grade is too steep to permit walking up or down without danger of slipping, therefore this portion of footbridge must be constructed as a long pair of steps, a length of 700 ft.

Another unusual feature, due to great length, is the necessity of providing a transporting system to get the men to their various stations on the footbridge. A man starting to walk from the anchorage to his station at the middle of the main span, would consume half an hour in making this journey. Due to steep climb up and down to each tower top, it will take one hour to walk from one anchorage to the other anchorage by way of the footwalk.

The Cable Contractor.—The problems of erection are greatly increased because of the extremely long span and requires extensive engineering research to solve the problems. Models of the bridge, constructed in exact proportion to size and weight, are being used to aid in the solution of the major problems. The Engineering Department of the Roebling Company, located at the General Offices, Trenton, N. J., is handling all phases of design and construction of these main cables. The actual erection work will start the latter part of this year and until November, 1929, the work will consist of erecting plant, equipment and footbridges necessary for the operation of constructing the main cables, which will commence in November, 1929. The date of completion of the four main cables is December 1, 1931.

The Field Offices will be located at the New Jersey Anchorage, from which point the erection work will be directed.

Pier construction is now under way, the foundation work now being done by the Silas Mason Company, Inc., New York City, general contractors, under the direction of O. H. Ammann, chief engineer of bridges, Port of New York Authority, and Montgomery B. Chase, engineer of construction; Daniel E. Moran, as consulting engineer on foundation for the owners.

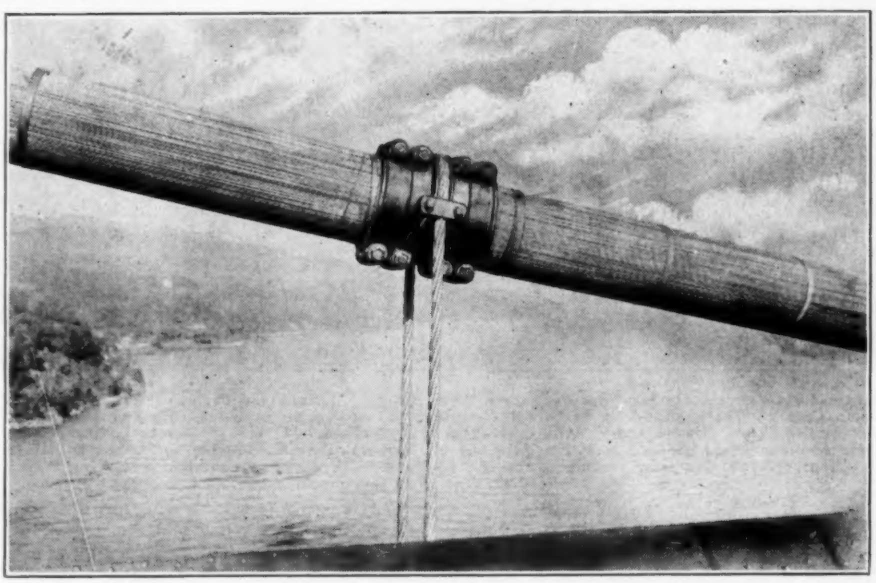


Fig. 4.—An Example of Correct Cable Construction. The Parallel Relation of the Individual Wires Can Be Readily Observed. There Is Also Shown the Steel Cable Clamp. This Clamp Forms a Saddle for the Suspender Ropes Which in Turn Support the Entire Weight of the Suspended Span

Sources of Highway Revenue and Expenditures

In his report presented at the annual meeting of the American Association of State Highway Officials, W. C. Markham, executive secretary of the Associated pointed out that state roads received 59.2 per cent of the net receipts from gasoline taxes and motor license fees. Federal contributions averaged 13.2 per cent. The remaining 27.6 per cent of expenditures came from (1) in some states a general tax levy (2) in others, a bond issue, (3) in others a special tax on benefited road districts and (4) in others from oil royalties, etc. Federal payments to states ranged from 2.6 per cent to 58 per cent of their total expenditures.

On the basis of $1,200,000,000 total expenditure, federal payments amounted to 6.1 per cent. The average gas tax was 2.7 ct. a gallon and the average license fee per car was $13.14. The highest road expenditure per capita was $20.24 in Nevada and the lowest was $2.65 in Georgia. For the whole country it was $6.47. Per $100 actual wealth the highest expenditure was 75 ct. in North Carolina and the lowest was 5 ct. in Delaware. The average for the United States was 23 ct. New Jersey spent $11,080 per mile, North Dakota $260 per mile and the United States $2,508 per mile, including in all cases only state system roads. Federal expenditures toward these same roads were 66 ct. per capita, 2 mills per $100 of wealth and $269 per mile. Two states, Maryland and Massachusetts, spent more for road maintenance than for new construction.

Construction Views on Irving Park-Desplaines River Bridge. 1—Subgrade Prepared for Widening of Highway to 40 Ft. 2—Converted Tractor and Dump Cars on Trestle, Used to Transport Concrete. 3—Automatic Adjustable Batcher Used on the Work. 4—Looking West on the Bridge, Showing Mixing Plant, Trestle and Dragline. 5—This Derrick Equipped With a Clamshell Bucket Moved Aggregates From Hoppers to Batcher. 6—View Looking East, Showing Relative Positions of Hoppers, Derrick, Batcher and Elevated Mixer. 7—View of West Abutment, Showing Mixing Plant, Trestle, Centering and Sheet Piling. 8—Form Work on East Abutment and Wing Wall. 9—View of Two Piers, Spans and Centering

Interesting Concrete Plant on Highway Bridge Job

Elevated Mixer and Overhead Car Haulage Solved the Plant Problem

IN THE course of widening the Irving Park highway running westward through Cook County, Illinois, affording an adequate 40-ft. pavement westward from Chicago, it was found necessary to erect a new bridge over the Desplaines River, near the intersection of Irving Park Ave. and the River Road, a north and south highway. The construction of this bridge has not broken any records, but the concrete mixing and handling plant used by the contractor, the Ray Mann Construction Co., was found to be a type worth study. Other points of interest will be touched on as well.

Type of Bridge.—This structure is a girder type reinforced concrete highway bridge of three spans of 63 ft. each, or a total length of 189 ft., with a 44-ft. highway and two 5-ft. sidewalks. Rails are of face brick. The design is of a type that is standard in Cook County. Abutments and piers rest on spread footings bearing on clay. This bridge, containing 1,855 cu. yd. of concrete, was designed for a maximum uniform loading of 125 lb. per sq. ft.

Centering.—The centering used to support the formwork for the spans consisted of closely spaced bents made up of wood piles and timbers. A six-man crew was required to drive the piles, and a 2,900-lb. drop hammer was used in this work.

Cofferdams.—The work on the two piers and two abutments reqiured for this bridge was facilitated by first constructing cofferdams of Lackawanna steel sheet piling, 22 to 24 ft. long, driven with a 2,900-lb. drop hammer to a penetration of ½ in. with a 15-ft. drop. Working 9-hr. days, the six-man crew could drive from 12 to 15 of these piles a day.

Excavating. — The excavation for piers and abutments was done with a Koehring outfit equipped with a crane boom, with most of the digging done with a clamshell bucket and some with a dragline rig. This machine, working in hard blue clay, averaged about 500 cu. yd. of excavation per day, and was available for other duty as required.

Form Work.—The form work was rather extensive. With 9 girders for each span and a little more than 2,000 sq. ft. of forms per span, a force of 6 carpenters was able to make and set up the forms for each span in 3 days, while each abutment requiring 2,200 sq. ft. of form work, could be formed and erected ready for concreting in 5½ days. Two steel setters were used in placing the reinforcing steel in the forms. Universal form clamps were used to tie the forms together, and the holes left in the concrete by these clamps were patched after the forms were stripped.

Concrete Specifications.—The structure was built of "Class A" concrete under the standard specifications of Cook County, which call for a 1:2½:4 mix with 6 sacks of water to the sack of cement, mixed for one minute, and cured under wet sand for 20 days.

Concrete Plant.—Aggregates and cement were delivered by motor truck to the mixing plant near the west bank of the river, using the River Road for these deliveries, and cement was unloaded into a cement shed, while sand was dumped into a wooden hopper at the side of the roadway fill, and gravel was likewise dumped into a similar hopper alongside the sand hopper. These two hoppers were about 15 ft. apart, and were below the roadway grade. Their function was that of acting as stockpiles. A stiffleg derrick was mounted between these bins at the side opposite the roadway, equipped with an auxiliary counterbalanced drum and double drum steam.

This derrick, equipped with a clamshell, was used to lift the aggregates out of these stock bins and load them into a Blaw-Knox 6-bag batcherplant located on the pavement opposite the space between the two bins.

Mixer is Elevated.—The concrete is mixed in a Rex 2-bag mixer, equipped with extension loader, mounted so that the discharge is about 15 ft. above grade and so that the charging skip when at the bottom of the extension loader is below the batchers. The materials are thus fed from the batchers directly into the charging skip and the batch is elevated in this skip to the mixer and discharged into the drum. Located just below the mixing platform, at about 10 ft. above grade, is the terminus of an elevated narrow gauge track running down the centerline of the road from the mixer to the bridge. On this track, three ½ cu. yd. Lakewood dump cars are used to transport the concrete from the mixer to the bridge. These three cars are moved by a Cletrac tractor that had been converted into a locomotive by removing the crawler mounting and mounting sprockets and rail wheels on the axles and which is then driven by a chain between the main drive sprocket and the sprockets on the wheels. This home rigged "locomotive" was able to move two cars of concrete, two batches to the car, over the 400-ft. haul at a maximum rate of 18 miles per hour. At the bridge end of this trestle, the cars of concrete were dumped into a field hopper suspended from the ties, and the concrete chuted from this field hopper to the forms.

Concrete Gang.—The work of mixing and placing concrete was done with the following average gang:

1 Foreman.
1 Hoist operator.
1 Mixer operator.
1 Hopper man (helps on cement).
1 Cement handler.
1 Switchman.
1 Locomotive operator.
1 Car hand.
3 Men in cement shed.
5 Puddlers.

With this force, and the equipment described, the plant was able to average about 120 cu. yd. of concrete per day when operating. Of course it was not possible to operate the mixer all the time, since high water and other factors interferred with the progress of the work, and since each span had to be cast in a continuous pour.

Those Responsible.—The work was done by the Ray Mann Construction Co., under the personal supervision of W. J. Mann. Design and construction were both under the control of the Department of Highways, Cook County, of which Maj. George A. Quinlan is Superintendent of Highways; W. E. Bates is construction engineer, while on the work in the field, the Department was represented by Henry Craning, resident engineer; Wm. Cryer, assistant resident engineer, and Wm. C. Snyder, inspector. The work of widening the highway involving this bridge was done under contract by the Iroquois Construction Co.

Pennsylvania Requires Standard Pavers

The Department of Highways, Commonwealth of Pennsylvania, has announced to division engineers and contractors that the department will not approve the overloading of concrete mixers on its contracts, that published mixer ratings, as agreed to by the Mixer Manufacturers' Bureau of the Associated General Contractors, are considered as the maximum size batch which will be approved for their work, and that in the future the department will not approve the use of any mixer which does not have securely attached thereto the proper rating plate which may be obtained from the manufacturer.

Vertical Curves—Their Function in Providing a Safe and Graceful Gradeline

Points of Layout Given In the Highway Magazine

By W. H. SPINDLER
Highway Engineer

IT is still a common experience in traveling over unimproved roads to reach the very summit of a hill without knowing what is beyond, either in the way of scenery or approaching traffic. Similarly at the foot of a hill, one still frequently experiences a resounding bump at the bridge or culvert, followed by an abrupt, steep upgrade. Correcting such conditions as these by a well designed gradeline with easy vertical curves is one of the essentials in improving our highways for present-day traffic.

The length of a vertical curve determines its ease or sharpness. Obviously, the flatter the approaching grades are, the shorter the curve need be; and the sharper the angle made by two approaching grades, the longer the curve needs to be.

Sight Distance.—A vertical curve on a summit must be designed for safe sight distance as well as driving comfort. At night, sight distance is a variable factor depending upon whether bright or dim lights are encountered.

For vehicles remaining on their own half of the highway or in their own traffic lane, long sight distance is of no great importance. It is when one vehicle attempts to pass another and then meets a third vehicle from the opposite direction that trouble arises. Lack of reserve speed or inability to get back in line may mean a bad accident.

Two vehicles approaching each other and each traveling at 30 miles an hour come 440 feet nearer in 5 seconds. Standards, then, requiring a sight distance of 400 feet on all vertical curves are only moderately safe, in view of the upward revisions of speed limits. Figure 1 gives recommended lengths of vertical curves for various algebraic differences in grade.

Departure from Standards.—The diagram (Figure 1) is based on a minimum sight distance. As a matter of fact, the sight distance obtainable is usually much greater. For ease in computing offsets, the vertical curve should be selected to the nearest 50 feet, although variations are permissible. Figure 2 gives a convenient method of computing offsets for vertical curves. For making grade revisions in the field, Figure 3 gives a quick means of finding the intersection point of given grades.

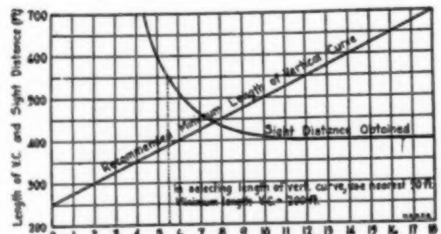


Fig. 1—Recommended minimum lengths of vertical curves based on 400 feet sight distance. Example: Assuming an algebraic difference in grade of 5.5 per cent, the recommended minimum length of vertical curve is 385 ft. Use 400 feet (nearest 50 ft.). The sight distance obtained is approximately 550 ft. with the eye and the object assumed at 4 ft. above the surface

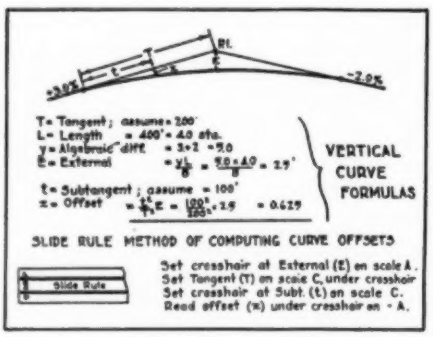


Fig. 2—A convenient method for computing offsets for vertical curves

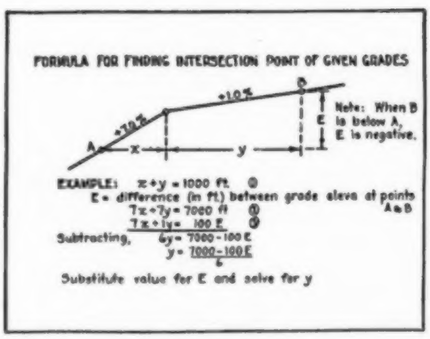


Fig. 3—A quick means of finding the intersection point of two given grades

A minimum vertical curve length of 200 feet, regardless of how slight the differences in grades, is a satisfactory standard. At railroad crossings a minimum vertical curve length of 100 feet for each curve is recommended. The curves may reverse or form a continuous parabola. Preferably, however, from 50 to 100 feet of level tangent on either side of the track should be allowed as a safety measure.

As a rule, cutting and filling in front of improved property should be a minimum. Each case is a problem in itself, and quite frequently requires a sacrifice in sight distance and the use of shorter vertical curves than otherwise recommended. Underlying rock strata, the presence of springs, or strata which may induce landslides, are also factors which influence the selection of vertical curves.

Rolling Grades.—There is economy in a rolling gradeline in rolling country. Exception is made where the undulations or waves are slight and the crests close together; here for improved appearance, the use of a long straight grade is advocated.

Rolling grades are formed by a series of compound or reverse vertical curves which may or may not be separated by long or short tangent lengths, depending on the profiles.

Sometimes the profile or topography is such that a very long vertical curve can be used to follow the ground line closely. Such curves give a pleasing appearance in the finished road, but represent considerable work to the man laying the grade, especially if his earthwork quantities do not balance readily.

Effect on Quantities.—In general, vertical curves in valleys increase the quantity of embankment material, and in cuts increase the excavation quantities. Frequently, however, the designer can adjust his grades and the cross-section in the cut so that the quantities are a minimum under the circumstances.

Summary.—Vertical curves are an important tool in the hands of the man laying grades. By means of them he controls the quantities of excavation and embankment. By their skillful use, he can make his quantities balance with a minimum of time and effort. Vertical curves perform a very important function in providing safe highways of pleasing appearance.

Asphalt Surface Treatments on West Virginia State Roads

Experiences of State on Several Types of Treatment Told at Meeting of Asphalt Association

By B. E. GRAY
Division Engineer, West Virginia State Road Commission

THE NEED for development of a greater mileage of highways is so well understood as to require no argument, and that the raising of additional funds for such purposes is an ever increasing problem is a fact well appreciated by all responsible officials. The answer to the problem lies in the greater use of low cost types of surfacing. I believe that in this field may be found one of the greatest opportunities for the highway engineer, as it must be borne in mind that the present State Highway systems comprise scarcely ten per cent of the total mileage of traveled roads, and that even this small percentage cannot all be improved with a high type of road surface for years to come.

A highway system is analogous to a railroad system in that it is purely a means of furnishing transportation service. The various lines of a railroad are improved according to the traffic which they are called upon to bear, and there is no reason why a highway should be improved on any other basis than that of making it adequate for the traffic which will come upon it. Accordingly, wherever it is possible to use local materials immediately available to the road side, and make surfaces which will give adequate service at a low cost, such a type certainly should be used rather than arbitrarily selecting some high type purely for reasons of sentiment or because of public clamor.

The subject of surface treatments may be well divided in two parts; under one, being included those treatments given to preserve the original surface (and which includes water bound macadam, puddle macadam, penetration macadam and other similar types of

Water Bound and Penetration Macadam

1—Preparing Previously Treated Water Bound Macadam for New Surface Treatment, Edge Patching to Gain a Foot Width and Hot Surface Treatment Will Tie It in. 2—Treatment with ¼ Gal. Hot Asphalt Per Square Yard, with ½ In. by 1½ In. Chips Applied at the Rate of 30 Lb. Per Square Yard. 3—After Hot Surface Treatment the Edge Patching Shows Darker But Gradually Blends in with the Rest of the Pavement, and Surplus Chips Whip Off and Stabilize the Shoulders. 4—Such a Pavement Three Months Old. 5—Cold Asphalt on Penetration Asphalt, One Year Old. 6—Hot Asphalt Treated Surface Four Years Old

surface) and under the other, those surfaces to which treatments are given as a dust palliative, or to improve and build up a better or higher type of surface.

The technique for the first group is pretty well established as a result of long years' experience, and refinements and changes are brought about only as asphalt manufacture is improved. In the second grouping, however, there is a great field for development, improvement and experimentation. I shall briefly run over the methods and materials used in handling the several types of surface treatments with particular reference to specification of material, cost, traffic, and annual maintenance cost.

Water Bound Macadam. — Water bound macadam is a type rather infrequently built today, yet there is a large mileage of such roads in every state highway system in the country which are giving excellent service results where bituminous treatments have been given. The first application consists of a light asphaltic material with a fairly high percentage of volatile elements which evaporate within a short time after application. We use a light asphaltic oil for the priming penetration with a cover coat of ⅝ x ⅝ inch chips. Two successive quarter gallon applications are better than a single one-half gallon application and about ten pounds of chips are required as cover coat for each application. The following year a single quarter gallon application will be required, with successive treatments about every three years under medium traffic, using somewhat heavier material. The specifications are given in Specifications I and III.

Penetration Macadam.—For penetration macadam, surface treatments should not be given until the surface shows pitted and the coarser stone begins to show exposed below the edges. I believe the mistake is often made of giving a surface treatment when all that is required is a little patching and the surface then carried over for another year. I recall some fifteen years ago when in Massachusetts, and before the precision of asphalt manufacture was anything like today, I worked with a Mr. Charles Howes, Division Engineer, who used to say to us every winter when we brought in our recommendations for the following season's maintenance, "A good rule for the time to surface is to let the surface go until it looks like it would go to pieces if it wasn't treated immediately, and then let it go for another year." While we didn't always agree with him, largely on account of the appearance of the road surface, yet it is a fact that to hold a smooth surface, the minimum application that will hold chips is the proper amount. In West Virginia we used two types of treatment on penetration, hot asphalt with 1¼ in. x ¾ in. chips and cold asphalt with ⅝ in. x ⅝ in. chips. The specifications for hot asphalt are given in Specification IV or V, and by cold asphalt in Specification III.

Hot Treatment.—In general, hot treatment is used on sections through the mountains where the coarse chip gives a roughened surface which is non-skid, and which will remain in the roughened condition for several years, or else on sections where it is desirable to increase the thickness of the wearing course. Hot treatments, while they do not produce that superior smoother riding surface which is so attractive, yet have a number of advantages. The material sets up almost immediately after application, and as soon as coarse chips are thrown on for cover, traffic can immediately use the road without picking up the chips or getting bituminous material on the car. Two successive hot treatments however, are never given, as there is a tendency to produce a wavy surface with the additional application and as the hot material never sets up quite as hard as the cold application. Hot asphalt is applied at the rate of one-quarter to three-eighths gallon per square yards and requires from twenty-five to thirty pounds of chips for cover coat.

Patching.—There may also be included in this first group of surface treatments, the item of patching, as it is often difficult to tell where patching leaves off and surface treatment begins. We have been using a cold asphalt patch during the past year which has been unusually satisfactory, in fact it is superior to any material we have used. In view of the much lesser cost of making the poured patch, and because of the very smooth surface that can be obtained, there would seem to be but little reason for using the mixed method in ordinary highway maintenance today. This cold patch is used not only as a repair material but as a method of widening narrow pavements (including concrete) and also for "evening up" rough pavements prior to initial surface treatment. The specification for this cold asphalt patch is given in Specification II.

While the general policy in West Virginia is to grade a road a year or two in advance of paving, this has not always proven practicable, and on roads where paving has been carried on simultaneously with the grading, some settlements have occurred on the heavy fills or in low swampy sections, which in places has resulted in a wavy and uneven surface. Prior to the first surface treatment of such surfaces, cold patching is carried on, checking with a straight edge, and continuing such patching until no further settlement occurs. Edge patching is concurrently carried on, widening all points where traffic tends to ride the shoulders. As fast as these patches pound down and settle, additional material is added until stability is obtained. By such edge patching, about a foot additional width of pavement is gained at each treatment. When the next surface treatment is made, the whole blends in together, and a smooth riding and also a good looking surface is obtained.

Cold Patching.—The most essential characteristic of any road is smoothness, as this is the criterion of the public for quality. With continued smoothness there of necessity is stability, and with a smooth surface there should be no need for surface treatments more often than every three years (except under heavy traffic), and with hot treatments even four years have elapsed between applications. As a general practice, however, and since cold asphalts have reached their present stage of accurate development, we favor their use, with light treatments not to exceed one-quarter gallon per square yard about every three years. In some cases one-eighth to three-sixteenths gallon every two years may be desirable. Cold asphalts have a greater stability after set-up and when applied at a rate just sufficient to hold chips, resist shoving and waving of the surface.

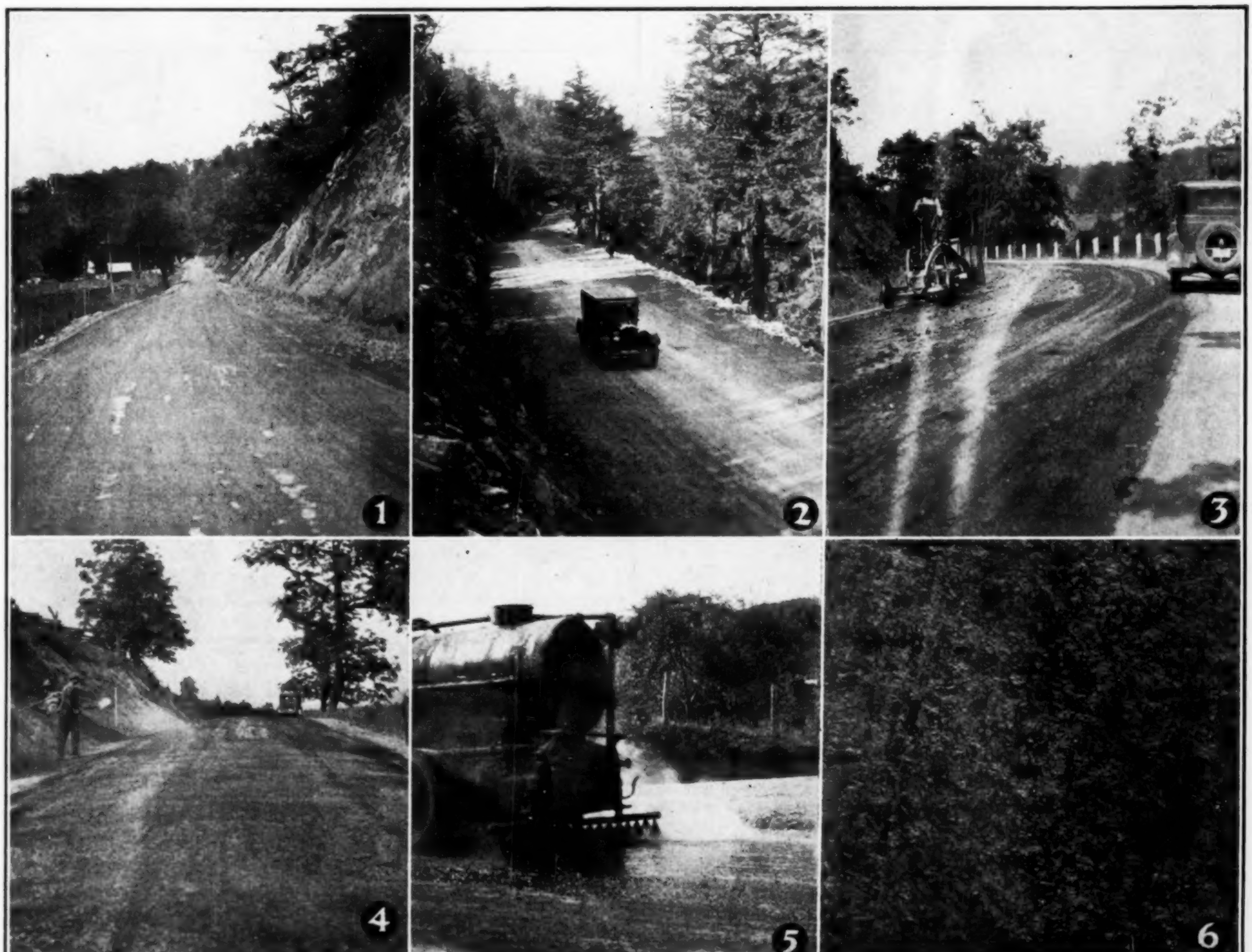
Gravel Roads.—So much for surface treatments and repair of standard macadam types of construction. It is in the second grouping that I am particularly interested, and wherein I believe the greatest amount of development may yet be carried on. In some states, difficulty has been met with in the surface treatment of gravels, but I believe that the whole reason for failure to achieve satisfactory results has been due to the use of an insufficient amount of asphalt. Gravels vary widely in grading and character and the satisfactory rate of application has to be worked out for each particular character of gravel. Gravels in West Virginia vary from the coarse sandstone gravels found in the small creeks to the commercial size gravel obtained from the Ohio and Potomac Rivers, and the method of treatment varies according to this grading. These are all sandy gravels with practically no clay, being all taken from stream beds, and should not be confused with bank gravels which have a large amount of clay, and require a different treatment. However, the degree of variation is simple and if the following method is followed, I do not believe that any difficulty will be experienced.

Treatment.—The general procedure is to allow the gravel to become well compacted under traffic, frequently blading the surface and adding new material until smooth and even. As soon as the surface has fairly well dried out in the spring, about the latter part of May or early June, it is lightly swept with a rotary sweeper and a quarter gallon application of cold asphalt applied with the distributor. The specification is given in Specifications I and III.

No cover coat is put on this first application and it is nearly all absorbed by the road surface. Several days later a second quarter gallon application is made and covered with ⅝ inch pea

gravel or chips. With fine gravels, this second application will usually be enough for the first season. If it absorbs pretty well, however, or is pitted, a third quarter gallon application is applied and again covered, and in some cases even the fourth quarter gallon application is made, and covered before a smooth uniform surface is obtained. This gradual building-up process is desirable, because there is no way of predetermining just how much asphalt will be absorbed by the surface as is the case with a macadam surface. These light applications should be added until the desired appearance of the surface is obtained, whether it is one-half gallon, three-quarters or even a gallon and no definite rule can be laid down. I wish to repeat that in my opinion practically all failures in surface treatment of sandy gravel have been due to inadequate amounts of bitumen, or else where there is an insufficient thickness of gravel to produce stability of surface. We have treated all kinds of gravel roads including the extremely fine chert gravel up to the very coarse creek gravels and with uniform success.

Shale Roads.—Nearly every section of the country has a local material which has given success as a road surface material in one form or another. The particular material easily available in West Virginia is shale. There are, however, an infinite variety of shales, some absolutely worthless as surfacing materials, while others produce an appearance very similar to first class water bound macadam. An interesting development in the use of shale has been the making use of previously gained knowledge, to predetermine whether a proposed material will give satisfaction, and even information as to where to look for such material. From time to time as shale has been used as a surfacing, chemical analyses have been made of each pit and at a later date comparisons made with service results so that a fair index of the worth of a material is now possible from a knowledge of its chemical make-up. In general a shale must contain from 55 to 65 per cent silica, from 6 to 10 per cent ferrous oxide and from 3 to 5 per cent magnesium and calcium to be a thoroughly stable material. If the clay content runs over 20 per cent, the material will break up badly during the winter. While these shales vary widely in their chemical analysis, the same kind of shale is usually found within the same geological horizon. Knowing, therefore, that a certain good shale can be obtained in a certain strata and by reference to a good geological map of any area, it can be predetermined fairly closely where to look for such material. By following out this practice, it has been possible to build some very excellent graded shale roads at low cost which are giving first class service. These roads are good summer and winter, but under fast moving traffic become dusty during the dry season and somewhat slippery during rainy weather. To overcome this, surface treatments have been given and in some cases have progressed beyond the surface treatment stage to the building



Treatment of Shale Surfaces

1—Shale Surface Failure Because of Insufficient Consolidation and Not Swept Before Asphalt Was Applied. The Remedy Would Be to Permit Traffic for a Month and Then Apply an Additional ¼ Gal. Application. The Potholes Will Then Close Up. 2—A Shale Road Being Prepared for Treatment, with Frequent Dragging in Spring Months. 3—Putting on Shale Cover from Windrows at Side, Using One Man Grader. 4—Touching Up with Shale Cover Coat from Sloper Beside Road. 5—A Shale Surface Receiving Second ¼ Gal. Application. 6—Closeup of Pavement After Three Years' Treatment, Using Shale Cover. Notice the Slightly Granular Texture.

Specifications for Asphaltic Materials Used in Surface Treatment Work in West Virginia

Specification I

Prime coat for water bound macadam, and for surface treatment of shale and gravel surfaces.

Material furnished under these specifications shall be a pure liquid bitumen, homogeneous in character, free from water or decomposition products, and shall meet the following requirements for chemical and physical properties:

	Min.	Max.
1. Specific Gravity at 60 deg. F.	0.935	0.950
2. Engler Specific Viscosity 1st 50 cc. at 122 deg. F.	10	18
3. Asphalt Contents at 100 Penetration	60.0 per cent	65 per cent
4. Evaporation Loss 50 grs. 5 hrs. at 325 deg. F.	24.0 per cent	30.0 per cent
5. Float Test on Residue at 122 deg. F.	60 Sec.	
6. Bitumen Soluble in CS_2	99.5 per cent	
7. Per cent of Total Bitumen Insoluble in 86 deg. Naphtha	14.0 per cent	

Specification II

Cold patch used for skin patching over hair cracks, hole patching, evening up patching and edge patching.

Material furnished under these specifications shall be a pure, highly volatile liquid bitumen. It shall be homogeneous in character, free from water or decomposition products, and shall meet the following requirements for physical and chemical properties:

	Min.	Max.
1. Specific Gravity at 60 deg. F.	.9350	.9500
2. Specific Viscosity Engler (1st 50 cc. at 122 deg. F.)	25	40
3. Evaporation Loss 20 grs. 5 hrs. at 212 deg. F.	24 per cent	
4. Penetration at 77 deg. F. on Residue from Loss at 212 deg. F.		125
5. Evaporation Loss 50 grs. 5 hrs. at 325 deg. F.		30 per cent
6. Penetration at 77 deg. F. on Residue from Loss at 325 deg. F.		115
7. Asphalt Contents at 100 Penetration	70.0 per cent	
8. Bitumen Soluble in CS_2	99.5 per cent	
9. Per cent of Total Bitumen Insoluble in 86 deg. Naphtha	18.0 per cent	

Specification III

For second application or seal coat on previously treated macadam—shale—gravel.

For cold surface treatment for previously treated bituminous macadam—shale—gravel.

Material furnished under these specifications shall be a pure homogeneous liquid bitumen, free from water and decomposition products. It shall meet the following requirements for physical and chemical properties:

	Min.	Max.
1. Specific Gravity at 60 deg. F.	.9400	.9650
2. Flash Point (Cleveland Open Cup)		95 deg. F.
3. Specific Viscosity Engler (1st 50 cc. at 50 deg. C.)	18	30
4. Asphalt Contents at 100 Penetration	68	
5. Evaporation Loss 20 grs. 5 hrs. at 212 deg. F.	25 per cent	
6. Evaporation 50 grs. 5 hrs. at 325 deg. F.	27 per cent	35 per cent
7. Penetration at 77 deg. F. on Residue from 325 deg. F. Loss		200
8. Bitumen Soluble in CS_2	99.5 per cent	
9. Per cent of total Bitumen Insoluble in 86 deg. Naphtha	15.0 per cent	
10. Distillation A. S. T. M.:		
Per cent up to 150 deg. C.	5	10
Per cent up to 200 deg. C.	24	29
Per cent up to 205 deg. C.		32

Specification IV

For hot surface treatment, medium chips.

Material furnished under these specifications shall be homogeneous in character, free from water and decomposition products, and shall meet the following requirements for chemical and physical properties:

	Min.	Max.
1. Specific Gravity at 60 deg. F.	.980	1.01
2. Engler Specific Viscosity 1st 50 cc. at 212 deg. F.	25	50
3. Asphalt Contents at 100 Penetration	85.0 per cent	
4. Ductility of Residue at 77 deg. F.	100 Cms.	
5. Evaporation Loss 20 grs. 5 hrs. at 212 deg. F.	10.0 per cent	13.0 per cent
6. Penetration of Residue at 77 deg. F.		200
7. Evaporation Loss 50 grs. 5 hrs. at 325 deg. F.	12.0 per cent	15.0 per cent
8. Penetration of Residue at 77 deg. F.		125
9. Bitumen Soluble in CS_2	99.5 per cent	
10. Per cent of total Bitumen Insoluble in 86 deg. Naphtha	20.0 per cent	

Heat with steam to 200 deg. F.

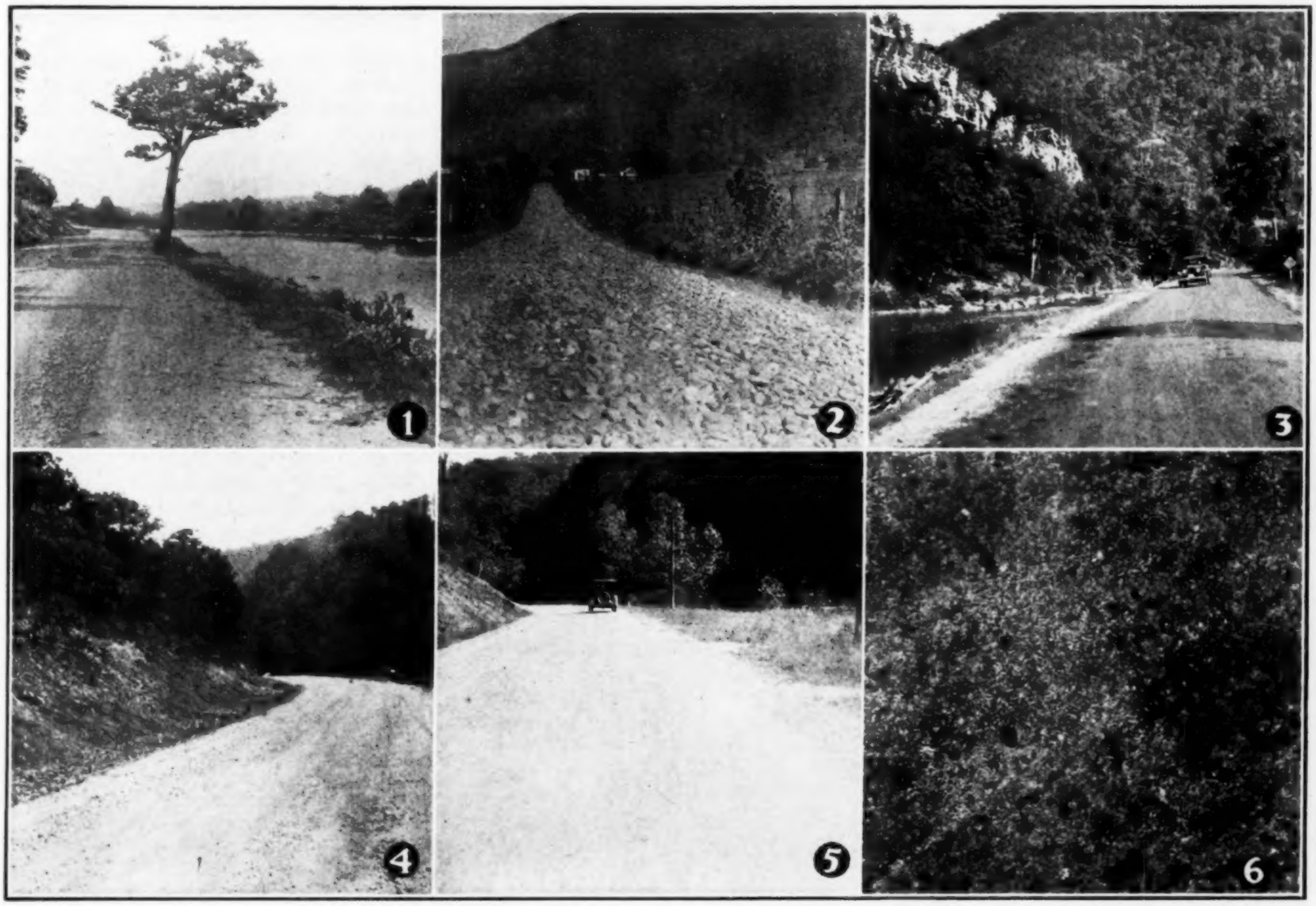
Specification V

For hot surface treatment, large chips.

Material furnished under this specification shall be homogeneous in character, free from water and decomposition products, and shall meet the following requirements for physical and chemical properties:

	Min.	Max.
1. Specific Gravity at 60 deg. F.	1.02	1.035
2. Float Test at 122 deg. F.	125	175 Sec
3. Flash Point (Open Cup)	385 deg. F.	400 deg. F.
4. Asphalt Contents at 100 Penetration	90 per cent	
5. Evaporation Loss 50 grs. 5 hrs. at 325 deg. F.		1.5 per cent
6. Float Test on Residue at 122 deg. F.	175 Sec.	
7. Bitumen Soluble in CS_2	99.5	
8. Bitumen Insoluble in 86 deg. Naphtha	18.0 per cent	

Heat with steam 350 deg. F.



Asphalt Treatment of Gravel Roads

1—River Gravel with No Binder Added. 2—Coarse River Gravel Surfacing. 3—River Gravel Road One Year After, Application of ¼ Gal. Cold Asphalt. 4—River Gravel 10 In. Thick Maintained Three Years Without Treatment. 5—River Gravel Base with 3 In. Macadam Top with ¼ Gal. Cold Asphalt Seal, One Year After Treatment. 6—Closeup of Cold Asphalt Seal Coat with ⅜ In. by ⅝ In. Chip Cover

up of thin macadam wearing coats. The first application is a cold asphaltic material which should not exceed 60 per cent 100 penetration asphalt content, see Spec. I. In May or early June the surface is lightly swept with a rotary sweeper and the cold material applied at the rate of about one-quarter gallon per square yard. With high grade shales there is practically no absorption of the asphaltic material (as is found with gravel), as the shale is very dense. Accordingly, it is necessary to apply cover to the first application, and this is done by carrying back the windrow of self-material that was swept off the road. This is done with a one-man grader. Places not covered with the grader are touched up by hand, taking additional cover coat from the edge of the road itself. Several days after the first application, a second quarter gallon application is made, which as a general rule fills all open places left by the first application and produces a thin bituminous mat uniformly over the entire surface of the road. One-half gallon is usually a sufficient amount for the first season's treatment. Roads so treated are extraordinarily smooth and easy riding, and far superior in such qualities over any other type of pavement. During the first winter, especially if there is much freezing and thawing, a considerable portion of the surface may break up and flake away, usually at those sections of the road where poor quality shale had been used or where drainage conditions had not been entirely corrected, rarely however, exceeding 20 per cent of the total mileage. Accordingly, with the next season's treatment there is a certain carry-over, so that on long stretches only a quarter gallon application is necessary to reproduce a smooth and uniform surface.

A Fast Job.—The great advantage of this method of treatment is the rapidity with which it can be carried on, as using the one-man grader and the self-material, the item of cover coat is almost eliminated, which in macadam surface treatments often makes up one-half the cost of the work. These asphalt treated shale roads have given entire satisfaction and over a large mileage are giving all the transportation service that could be obtained from the very highest type of construction. Such roads have carried as high as 1,000 vehicles per day,

Table I—Showing Asphalt Treatment Costs

Type	Cost of Initial Surface Treatment Per Sq. Yd.	Period Between Treatments	Annual Maintenance Per Sq. Yd. Including Patching	Traffic
Water Bound Macadam	.09 ½ Gal.	1 yr. to second 3 thereafter	.04	500 to 1,000
Puddle Macadam	.05 cold .10 hot ¼ Gal.	1 yr. to second 3 thereafter	.03	500 to 1,000
Penetration Macadam	.05 cold .10 hot ¼ Gal.	3 years	.03	500 to 2,000
Cold Patch and Widening	$6 per ton complete in place including everything. Requires 12 gal. per ton with 1¼ chips plus 8 gal. per ton with ⅝ chips to seal. Total 20 gal. per ton of stone.			
Gravel	.13 cold ¾ Gal.	Average every two years	.10	200 to 800
Shale	.05 cold ½ Gal.	Annual	.06	300 to 800

but average from 300 to 800 summer traffic and 200 to 400 winter. Sometimes during the latter part of the season there will be places that will ravel and it is desirable to go over the surface with a patching crew, touching up such ravelled places by merely sprinkling on the cold asphalt and covering with a shovelful of shale from the side of the road. The cost of such repair runs about $10 to $15 per mile.

Work of this kind is a direct challenge to the highway engineer of today. It is no particular trick to build a $50,000 per mile road where all materials are available of the best; it simply requires attention to details in carrying out the specifications to produce a satisfactory road, but where funds are limited, where the need is great, and where a satisfactory road can be produced for three or four or five thousand dollars per mile which gives entire satisfaction to the travelling public, then I believe the engineer performs a real service. I know of no material which lends itself to work of this nature any better than asphalt. There is a grade for every need, and I believe that we are just beginning to find out the infinite variety of uses to which it may be put, and that in the future, we will be obtaining satisfactory surfaces at low cost, from materials which have not been formerly included in the specifications.

Ohio Adopts Steel Grit for Use in Core Drill Tests

The Ohio State Highway Department is now using steel grit in its core drills for cutting test sections of pavement. Steel grit is simply crushed steel shot carefully screened to standard size. It costs about the same as steel shot, but offers sharp cutting edges while steel shot is round and smooth.

No. 8 grit, which just passes through an 8-mesh screen (opening .093 in.) is the size usually used for core drill work.

Extensive use by the Ohio State Highway Department is stated to show that steel grit cuts much faster than steel shot. Shot was always very slow on brick; with grit they cut through a 2½-in. brick in seven minutes. Gravel concrete is usually very hard to cut through since most gravels contain some very hard pebbles. 8 to 10 cores was a good day's work in this material when shot was used. With grit 12 to 15 cores is an average day's work.

The steel grit feeds well and costs about the same per pound as steel shot, and very much less per core.

The American Steel Abrasives Co. of Galion, O., who manufacture this material, have offered to send generous test samples of No. 8 steel grit, without obligation, to any core drill user who desires to test the material.

Asphalt Cold Patch Work

1—After Widening to 18 Ft. and Surface Treatment Over Whole Width. 2—Rehabilitating and Widening 12 Ft. Road to 18 Ft. with Cold Patch. 3—Rehabilitating Narrow Macadam Road with Asphalt Cold Patch. 4—Cold Patch Edge Widening, Letting the Traffic Iron Out the Material. 5—Edge Patching and Widening, Using Cold Patch. 6—Cold Patch Shoulders on 14 Ft. Concrete Road

Obtaining Efficiency in Concrete Road Construction

Things to Be Watched in Order That the Job May Pay Satisfactory Profit

OBTAINING efficiency in the construction of concrete roads necessitates a careful study of production, transportation, equipment and organization. The results of such studies should bring to light many ways in which the construction work can be speeded and maximum efficiency more nearly approached.

Studies made by the Bureau of Public Roads indicate that there are few concrete paving projects on which the average daily output cannot be increased 25 per cent. On many jobs output can be increased 50 to 100 per cent accompanied by some reduction in the amount of labor and equipment employed.

No paving project can be accomplished with maximum efficiency unless 100 per cent output is obtained from a properly equipped job by a crew of the proper size. But what is 100 per cent output on a paving project? Assuming that the specifications governing the construction require a one minute mix, full production is obtained when 48 batches per hour—one batch every 75 seconds—are put through the mixer. By whatever amount a contractor fails to meet this standard he is failing to reach full efficiency. To attain this standard it is absolutely essential that the discharge be opened and the skip started up at the same time. There is an average lag of 5 seconds in charging the mixer after the skip has reached a vertical position; there is also a discharge lag of two seconds which partly offsets the lag in charging. The difference in time, or three seconds, should be added to the time of mixing.

The Mixing Cycle.—To maintain the standard of a 75 second mixing cycle, the operations must be reduced to approximately the following time limits:

1. Specified mixing time		60 seconds
2. Lag in charging	5 seconds	
3. Less lag in discharge	2 seconds	
4. Net lag effecting timer		3 seconds
Normal setting of timer		63 seconds
5. Lag in discharge		2 seconds
6. Simultaneous rising and discharging		10 second
Total mixing cycle		75 seconds

It is evident from this that a slow or inefficient mixer operator can lose considerable money for the contractor every day. Regardless of the available supplies, the equipment, the amount of skilled labor or other favorable conditions which may prevail, it must be remembered that the mixer is the bottle neck of every concrete paving job. It sets a rigid limit on production, the maximum of which will depend entirely on efficient operation in passing materials through it.

Mixer Maintenance.—Mixer trouble is expensive. Delays due to mechanical breakdowns of the mixer average about five per cent and may run as high as 10 per cent of the total time of operation. A contractor with an average daily pay roll of $200 may lose from $2,000 to $4,500 a season from this cause alone. The amount lost would practically pay for a new mixer in two or three years. Careful maintenance of the mixer pays. Full production cannot be maintained without it.

Water Supply.—Water supply is another source of trouble which makes heavy inroads on maximum daily production. Long lines of 2-in. water pipe are inadequate to supply the needs of the modern 5-bag mixer. The high pressure needed to force water through them bursts hose, splits pipe, opens joints and springs the mixer valves. A leaky mixer valve causes more trouble than is at first apparent. Non-uniformity in the consistency of concrete is one of the ills of the leaky valve. This makes finishing difficult and slows down production. It causes the mixer operator to make guess work of the amount of water he adds to the batch in the drum. Changing the mixer hose connection is another common cause of delay. This can be avoided by providing a double lead of hose from the mixer to the pipe line, one lead connected near the mixer and the other attached as far ahead as possible. Then the changing of the hose connection becomes a matter of closing one valve at the mixer and opening the other. The rear hose can then be carried forward by a few men at a time most convenient. Meanwhile, the mixer is supplied with water through the front lead of hose. Three-inch pipe will carry an adequate water supply at a reasonable pressure and will reduce water trouble and increase output.

Other Delay Causes.—Lack of prepared subgrade, poor form setting, slow delivery of materials and inadeqaute truck supply are other causes of delay which prevent full production. All of these can be avoided and are inexcusable on a well managed job. Arbitrary interference by inspectors and abuse of discretionary clauses in the specifications also cause delay. Such interferences can best be avoided by a complete understanding with engineers and inspectors at the time the job is begun.

The Controlling Element.—The mixer on a concrete paving project is comparable in all respects to an army in the field. Neither can do the work intended without efficient functioning of the "S. O. S." (service of supplies). The mixer and the crew of men about it are but a unit of an organization composed of many units which must be perfectly synchronized in order to give full production. If the mixer is to turn out 1,000 ft. of paving every day, the subgraders must prepare that much subgrade every day, the form-setters must set 1,000 ft. of forms every day, railroads must deliver a quantity of material for that much pavement each day, the proportioning plant must handle the material, an adequate number of trucks must be on hand to haul it to the mixer, the finishing crew must be able to finish that much pavement and an adequate supply of water must be available for mixing and curing every day. All of these units must function perfectly and must be gauged by the pacemaker—the mixer.

Delivery Systems.—The problem of balancing the delivery of materials to the mixer so as to maintain full capacity is not always a simple one, and every new job offers new transportation problems. The three recognized systems of material delivery are: (1) Delivery by batch trucks and dumping material directly into the skip of the mixer, (2) Delivery by industrial railway to mixer, each batch in separate box which is lifted by a crane at the mixer and material dumped into skip or mixer, (3) Delivery by wagons or trucks to the job where the aggregate is deposited in piles along the subgrade and moved to the skip in wheelbarrows. The first method is most commonly employed, and the trucks have a capacity of from one to four batches.

One of the first essentials before starting paving operations on a new job is to estimate the number of trucks which will be required to give full production at the mixer. This will be dependent on several variable factors. Some of these factors are, the length of haul to the mixer, the condition of the road, the number of batches carried per truck and the speed of the trucks.

Truck Formula.—Field studies have indicated that it takes four minutes to service single batch trucks and six minutes for two batch trucks. These servicing operations are, loading the fine and coarse aggregates, loading cement, turning at the mixer and discharging into the skip. To the time required for these operations about one minute should be added for unavoidable delays. Taking these facts into consideration,

the number of tracks required can be estimated from the following formulas:

For heavy duty two batch trucks..........T=10d/6
For high speed two batch trucks..........T= 6d/6
For ordinary single batch trucks..........T= 8d/4

in which T is the time required for one round trip and d is the distance in miles from the proportioning plant to the mixer.

For example, if the haul is 5 miles, how many of each of the above types of trucks would be necessary to provide a full supply of material for the mixer, operating at 100 per cent efficiency for ten hours a day?

The solution is as follows:

Batches required—48 per hour for ten hours=480 batches.
Working day—ten hours at 60 minutes=600 minutes.

For two batch heavy duty trucks. Formula 1	For two batch high speed trucks. Formula 2	For ordinary single batch trucks. Formula 3
$T=\frac{10\times 5=50}{6}$	$T=\frac{6\times 5=30}{6}$	$T=\frac{8\times 5=40}{4}$
Time per trip 56 min.	Time per trip 36 min.	Time per trip 44 min.
$\frac{600}{56}=11$ trips per day	$\frac{600}{36}=17$ trips per day	$\frac{600}{44}=14$ trips per day
$11\times 2=22$ batches per truck	$17\times 2=34$ batches per truck	$14\times 1=14$ batches per truck
$\frac{480}{22}=22$ trucks required	$\frac{480}{34}=14$ trucks required	$\frac{480}{14}=35$ trucks required

Roadway Maintenance.—To obtain full efficiency from the trucks available requires that the roads over which they travel be kept in the best possible condition. The financial aspect of this item can best be realized by referring again to the contractor's daily pay-roll of approximately $200 per day, and the additional depreciation charge of at least $100 a day which must be added thereto. Time, therefore, costs the contractor about 50 cents a minute. If bad roads prevent the trucks from delivering a sufficient number of batches to the mixer to keep it running at full capacity, it is possible for the contractor to lose a considerable amount of money in a very short time. This condition should be remedied immediately. The amount of money spent to maintain the roads being hauled over will be saved many times over in increased production at the mixer in one day's time. The fact that the hauling had been sublet does not change the situation in the least. Good roads to haul over are essential at all times and under all conditions.

Trucking Schedule.—At the beginning of paving operations it is desirable that driving schedules be worked out and that speeds which will allow the trucks to make the round trip in a definite time be set. Trips to and from the mixer on scheduled time have many advantages. Such a schedule prevents driving at high or low speeds which causes trucks to bunch at the mixer or at the loading plant and destroys regular delivery of materials at the mixer. If the truck supply is just sufficent to feed the mixer, the slightest delay in loading or unloading a truck, or any other interference along the line, will cause the mixer to drop a batch. To avoid this possibility it is advisable to operate an extra truck. There should also be a stand-by truck on the job ready to be put into operation immediately in event any one of the regularly operated trucks should become disabled or be withdrawn from the running schedule at any time. The additional cost of a stand-by truck will be more than repaid by increased production at the mixer.

Subletting Hauling.—During the past few years the practice of subletting the hauling to private individuals or companies has become common. This practice has many advantages for the contractor as well as some disadvantages. To maintain a large fleet of trucks would entail an additional expense on the contractor and there would be many occasions when a large fleet of trucks could not be used and consequently at least a part of the idle trucks would not earn the fixed charges placed upon them in a year's time. Whatever part of the hauling equipment was in operation would necessarily be compelled to earn greater fixed charges in a comparatively short period of time during the construction season. This does not hold true with the trucking companies, as they are able to earn additional revenue in other lines of industry. To sublet the hauling relieves the contractor of operation, maintenance and depreciation expense on a very costly part of organization equipment.

Hauling Contract.—The danger of subletting hauling of materials lies in the elasticity, or rather, in the lack of elasticity in the contract. The contractor should bear in mind that he can not possibly operate at full capacity unless sufficient material is delivered to his mixer at all times. A contract for hauling should be so drawn up that it will be binding as to price. Prices should be regulated on a sliding scale according to the length of haul. The contract should also specify the number of trucks which are to be supplied for various units in the length of haul, however, especial thought should be given to possible increase in efficiency of the contractor's organization in which case additional trucks will be needed to keep the mixer running at full capacity. On this point the contract should be elastic enough so that the contractor can demand additional trucks if they are needed. He can not afford to endanger the maximum production he is striving for by a hauling contract loosely drawn.

Moving Plant.—Probably one of the greatest assets on a construction job is mobility of equipment. The advantages of full production at the mixer and short haul in the service of supplies are soon lost if the equipment on the job is not efficient. The ideal type of equipment is that which can be moved with great rapidity between quitting time at night and the resumption of work on the following morning. This is especially true in connection with a change of location of the proportioning plant. It should be so designed that it can be dismantled quickly, loaded on trucks and moved to the new location and again erected in a few hours' time.

Aggregate Bins.—The up-to-date contractor has very generally adopted the steel bin. These can be moved from job to job quickly and they last a relatively long time. The home-made bin is rapidly going out of use because it is not mobile and is decidedly erratic in measurement of materials. The modern steel bins deliver the materials to the trucks about four times faster than the old type wooden bins.

Plant Layouts.—The layout of the material plant is of great importance in securing full production at the mixer. On most every job the material is delivered to the job by rail and the layout should be such that there is room enough for a crane to work between the cars and the bins or the storage piles. In this manner a crane can unload the cars as they are "spotted" and keep the bins filled at all times or can unload the excess material in the cars directly onto the storage piles. By this system the greater part of the material is handled only once by the crane. The crane should be of the crawler type with a ¾ yard bucket. It will be found that this type of equipment can satisfactorily supply enough material to the bins to keep them filled at all times and unload the cars that are "spotted" at the same time, thus avoiding demurrage charges.

Winter Stock Piles.—In this connection it might be well to mention that winter stock piling is expensive. In general rail delivery is so dependable that if shipments at the source of supply are made according to schedule and the mixer is operating with reasonable efficiency, upwards of 75 per cent of the material will go from the cars directly to the job. The other 25 per cent goes to the stock pile. This generates an average handling of materials of about 125 per cent. If the materials are stock piled during the winter there is 100 per cent unloading onto the stock piles which in time become so large that much of the material must be

shifted once or twice to get it to a place from where it can be loaded into the hoppers.

Handling Cement.—Handling cement remains today as one of the most inefficient operations on most paving jobs. It is generally a manual operation of lifting. Under these conditions it requires five or six men to load cement onto the trucks. Much of this inefficiency can be overcome by making the operation one of dumping instead of lifting. This can be accomplished by the use of a belt conveyor from the car or cement house to a raised platform on which hoppers have been built. The required amount of cement can then be dumped into the trucks as they pass under the platform. It will be found that the cost of handling cement can be reduced by one-half by the use of this system.

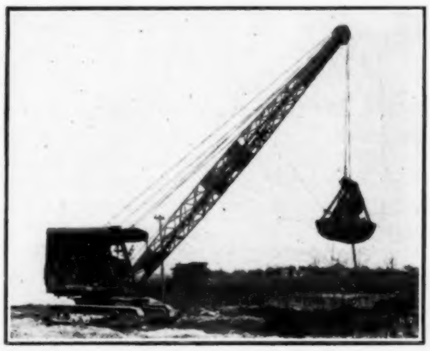
Subgrading.—As has been stated before, if the mixer is to run at full acpacity at all times, the subgrading crew working ahead of it must prepare the maximum amount of subgrade every day. Efficiency in the preparation of subgrade is determined by the number of times earth must be handled before concrete is placed upon it. Subgrading was purely a manual operation at one time, however, modern methods and machines have made this operation largely mechanical. The most economical method of finishing the subgrade is as follows: (1) Rough grade to mean elevation, (2) Cut extra edge thickness with blade, cutting wide enough to set forms, (3) Trim out for and set forms by hand, (4) Blade material for crown to approximately final position in center of road, (5) Scarify subgrade to a depth of at least 2 in. below finished grade, (6) Cut subgrade to exact shape with standard subgrader, (7) Roll lightly with light weight roller, (8) Drag fine grader back of mixer to care for distortions which may have occurred since subgrade was finished. These operations are about as completely mechanical as it is possible to make them at the present time and involve the least possible handling of material.

Finishing. — Maximum production cannot continue throughout the day unless the concrete is finished as rapidly as it is placed. There are two general types of finishing machines—the tamper type and the sliding type. Both do good work. Moreover, if the consistency of the concrete is uniform these machines will produce a surface which is so accurate that one man with a long-handled float and a ten foot straight edge can do the work of finishing. Uniformity of consistency is the secret of good finishing. Wet batches have a tendency to flow and settle and a smooth surface is more difficult to attain. The same troubles exist when there is an alternation of wet and dry batches. Wet concrete is perhaps easily puddled into place, but finishing is slow and is apt to fall far behind the mixer and cause a shut down until finishers can catch up with the work. This is an illustration of how improper consistency can reduce production.

Superintendence.—And last, but not least, there is need of better superintendence on the job. The various units are apt to be in control of a foreman who is fairly well acquainted with the best methods of operation for the particular unit he has in charge. It is up to the superintendent, however, to study the operations of the various units from a standpoint of increased efficiency. He should devise means of improving the operations of each individual unit and should have the ability of quick decision in case of emergency so as not to disrupt the operations should such emergencies arise. An approach to full efficiency can not be made unless all of the units have been fully synchronized in their operations in relation to each other.

Bay City Announces New Convertible Excavator

Following a period of severe tests the Bay City Type-R is publicly announced as a sturdy, compact, ¾-yd. convertible shovel, crane or trencher, with the assurance that it is ready to take its place in the contracting field along with the Bay City Tractor Shovel and Model 16-B Convertible Excavator.



Bay City Excavator with 35-ft. Boom and ¾-yd. Clamshell Bucket

The Model-R is a sturdy, compact machine now available with standard ¾-yd. shovel dipper with Manganese steel detachable and reversible teeth and hinges, with heavy Missabbe type, all Manganese rock dipper, reversible Panama teeth ⅝-yd. capacity, with crane boom in lengths of 35, 40 or 45 ft. to handle loads up to 10-tons (at 12-ft. radius) and crane buckets ranging from ½ to 1 cu. yd. clamshells, and ¾ to 1 cu. yd. draglines, and with Trench Boom and Scoop with trencher buckets ranging from 18 to 42 in. in width with a maximum digging depth of 20 ft.

The Type-R Bay City is full crawler mounted with long and heavy crawlers with extra width tread shoes, of standard Bay City design, with tread rollers enclosed on top and both sides to keep out dirt. The treads are self-cleaning. The machine is one-man operated and very compact in design, is provided with either gasoline or electric power, and a fully enclosed steel cab with doors and windows.

The Type-R does not radically differ from standard and accepted full-revolving shovel design excepting in the following particulars:

The machinery arrangement is compact, with parts easily accessible. The distance from the base of boom to the king-pin or center of rotation is only 30 in. or 1½ ft. less than the average distance between these two points on other full revolving machines of the same capacity. This feature is said to increase the stability of the machine and permit the lifting of heavier loads and greater operating radius.

The Crawler steering mechanism is new in design and covered by patent applications. This patented steering permits the quick and easy steering or turning of the machine by the operator without leaving his lever position or making any adjustments or changes in connection with the propelling mechanism, without stopping to shift jaw clutches, according to the manufacturers.

The machine table revolves on a large diameter heavy cast circle mounted on the car-body with large diameter rollers. This circle extends a little beyond the width of the car-body, giving the machine stability and eliminating tipping or rocking on the center post, increasing stability and permitting more accurate cutting on a fine grade, it is said.

Tail swing is short, permitting operation in crowded quarters. Lubrication of all parts located under the revolving base is accomplished by the operator without bending over or getting under the machine. A battery of a dozen Zerk-Alemite connections is located at the front of the main car body under a protecting plate, so that the operator can lubricate all parts under the revolving base from the one location without moving.

The approximate operating weight is 26-tons and standard equipment includes such conveniences as electric starting equipment for engine; Timken roller bearings on high speed shafts, etc. A 5½x7 in. 4-cylinder Climax engine operated at a speed developing 62 horsepower is listed as standard equipment. Drums are operated by E-Z control clutches with all operating levers in a convenient bank in front of the operator. Machine ships or travels completely assembled without dismantling, excepting for crane boom.

The Land Leveler as a Medium of Earth Transportation in Sub-Grade Construction

Method and Costs of Tractor Handled Equipment on California Job

By W. H. BALLARD
Superintendent of Construction, Santa Fe Land Improvement Co.

DURING the season from January, 1928, to the present time, July, an extensive road construction program has been in progress on Rancho Santa Fe, Cal., for the purpose of opening up new subdivision units.

The specifications called for subgrades varying in width from 18 ft. to 24 ft., to be paved or surfaced, with bordering walks and parkway areas. This necessitated preliminary rough grading of roadways ranging from 24 to 50 ft. in width. Construction has been conducted on a force-account basis under the direct supervision of the Santa Fe Land Improvement Co.

The Equipment. — Equipment was rented from U. L. Voris, a general contractor of San Diego County, and consisted entirely of Best caterpillar tractors with Holt and Throop land levelers (sometimes known as ground planes), Russell graders, Killifer sub-soilers and Towner sub-chisels. At the peak of the program two Best-60's and two to three Best-30's were used, but for the greater portion of the work one '60 and two '30s have been able to keep sufficiently ahead of water main and electric conduit installation. The '60s use Holt 5.0 cu. yd. capacity and Throop 3.5 cu. yd. capacity levelers, Killifer 3-standard subsoilers and a Russell super-special grader. The '30s use Throop 2.5 cu. yd. capacity levelers, Towner sub-chisels, Killifer 1-standard subsoilers and a Russell standard No. 3 grader. For the construction of bordering parkways and walks, a 2-ton Holt or Cletrac with a 1.5 cu. yd. capacity Schmeiser leveler and a Fordson-powered 1-man grader will be used. The operators of all these units have been exceptionally proficient men and deserve great credit for the type of work accomplished. The standard working days are 9 hours, but during the peak of the work this was increased to 10 hours.

General Conditions.—The earth encountered ranged in workablity from a fine loam, through sandstone and decomposed granite to clay and adobe. Since much of this work was carried on in late winter and spring, the soil conditions retarded progress appreciably.

Road lines were engineered to follow as nearly as possible the natural contours, avoiding through cuts where possible. However, much of the country worked through was extremely rugged and necessitated heavy cuts and fills.

This article is republished from the August issue, omitting the photographs that were shown in that issue, in order to show three charts that were not published last month since they were not then available. These charts, as explained by the reprinted text, will prove very interesting.

Grades varied from 2 to 9 per cent. Cuts ranged from 3 to 15 ft., and fills from 3 to 20 ft. As it is a policy of the Santa Fe Land Improvement Co. to mar and deface as little as possible the slopes bordering their roadways, side borrows were prohibited. This policy made necessary the complete construction of roads from material within the roadway limits, and led in some cases to dirt hauls up to 750 ft. in length.

How the Data Were Collected.—Having used heretofore only teams and team equipment in the construction of roads, terraces, drains and the like, the writer was most anxious to make unit cost and efficiency comparisons between this type of equipment and tractor hauled levelers. As the work progressed therefore, daily observations and records were made and rechecked as to time, cost, yardage loaded and yardage delivered over station distances. Since much of the material was moved during the wet months while in a condition which with team equipment would have been considered as almost unworkable, it was possible to obtain a very wide and varied assortment of data. When these data through repeated checking in the field appeared truly representative for the different types of equipment used, in various earth conditions, unit curves were plotted, as shown in Figs. 1, 2 and 3.

Unit costs are not given, as equipment rentals vary greatly in different localities, and such figures might prove misleading. By applying local equipment rates in terms of cost per minute of operation to the graphs given, the unit cost of earth transportation may readily be reached. Individual results may be obtained by applying the formula:

$$C = \frac{SxT}{E}$$

in which C=Cost Per Cubic Yard Delivered

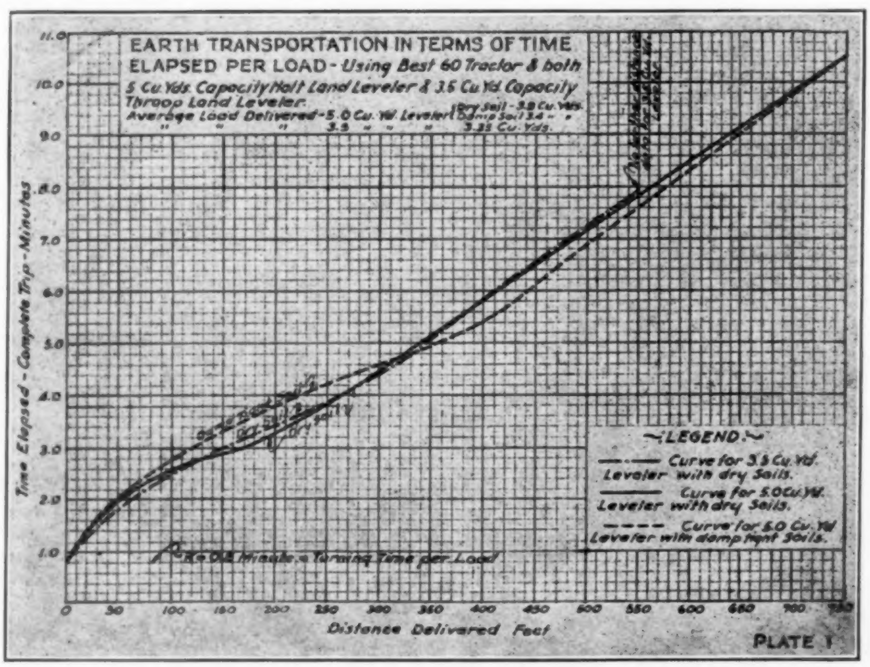


Fig. 1—Earth Transportation in Terms of Time Elapsed Per Load in Dry Soil and Damp Soil

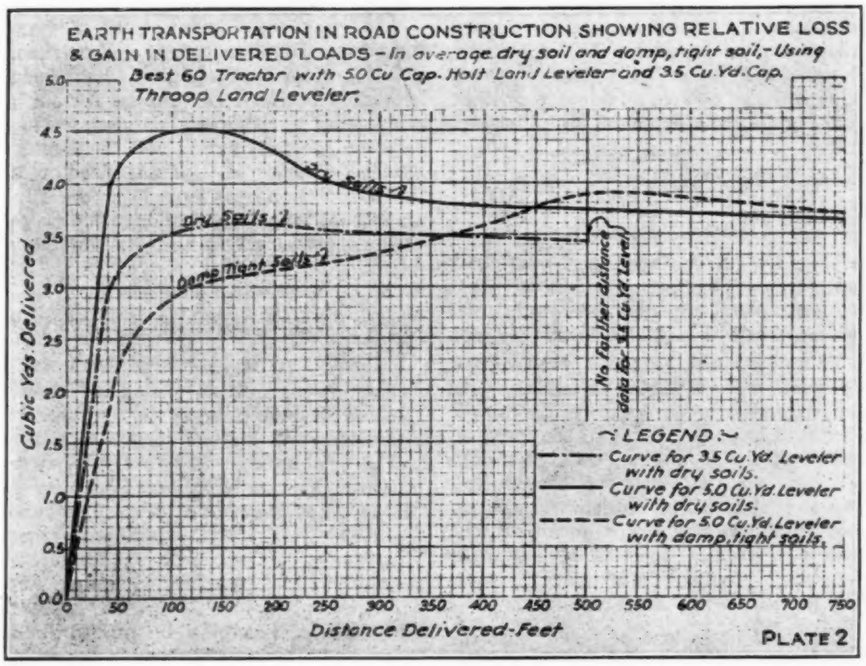


Fig. 2—Earth Transportation Showing Relative Loss and Gain in Delivered Load, in Average Dry Soil and Damp, Tight Soil

S=Cost Per Minute of Operation

T=Time Elapsed Per Load Delivered in Minutes

E=Cubic Yards Delivered

If the above formula is used, great care should be taken not to assume that the result obtained is representative, but several experiments over equal distances should be observed for a true average. Since the curves have been obtained through repeated experiments, they are perhaps more safe to use in estimating costs. Even allowing for the wide average of results from which the graphs are derived, it is well to add from 10 to 12 per cent for a safety factor to results shown by them. This will usually cover loss of time from delays, minor breakdown, etc.

Curves Based on Transportation.—It must be borne in mind that these results are based solely on transportation of earth in construction, and costs derived therefrom would not include the loosening of earth with a plow, scarifier or subsoiler, nor the blading of the roadway with a grader. In other words the leveler couples the functions of an immense fresno with those of rotary scrapers, wheelers, and in exaggerated cases, of dump wagons, and with the added advantage that the leveler constructs as it travels, constantly planing slight elevations and filling small depressions. However, as a means of conveying earth en masse over considerable distances where spill might be unnecessary or undesirable, as to a waste dump, or through city streets, the leveler would not be practical, as with dry soils there is always a certain loss in transit due to the inequalities over which it travels.

Another point to be remembered in applying the accompanying curves is that they are based on complete cycles of haul and return. They could not be accurately applied to a series of pick-ups and dumps with intervening empty hauls, excepting to show yardage delivered over stated distances. Such a condition embraces so wide a range of factors that to present it graphically would be impractical.

A distinct advantage over fresnos lies in the leveler's ability, especially the larger types, powered by a '60 or similar tractor, to maintain a more level plane of roadway during construction, thus giving an easier and more economical finish. Perhaps this will conflict with the observation of other construction men, but such certainly has been the writer's experience.

Operation of Levelers.—With skilled operators it is quite simple to construct embankment with the leveler without "breaking-over" with the load. By its ability to waste smoothly when desired, it eliminates much of the lack of uniformity and undulation to bank-edges so tedious to remedy.

The weight of any of the larger types of leveler is such that its blade will bite deeply into firm earth, or partly broken stone, saving much loosening with plow or scarifier. Particular mention is made in this respect to the 5.0 cu. yd. type, though good results were had with the Throop 3.5 cu. yd. implement. The latter was found slightly more retentive of earth on long deliveries (400 to 550 ft.), due, perhaps to the more curved construction of its pan.

Turning area is of course an important consideration, both in time and convenience. More particularly is this true of the '60 and large leveler. This type of equipment must either find a location in the roadway or adjacent to it, wide enough to execute a full circle (a diameter of 40 ft.) which in precipitous country is often difficult, or it must "back and fill." It was found more economical to travel empty a distance of 150 ft. to another pick-up than to "back and fill" once. The Best-30 and its equipment can of course turn in so short a radius that loss of time in that respect is not a factor.

The constant "K" appearing on curves represents the total turning time elapsed in one complete round trip,

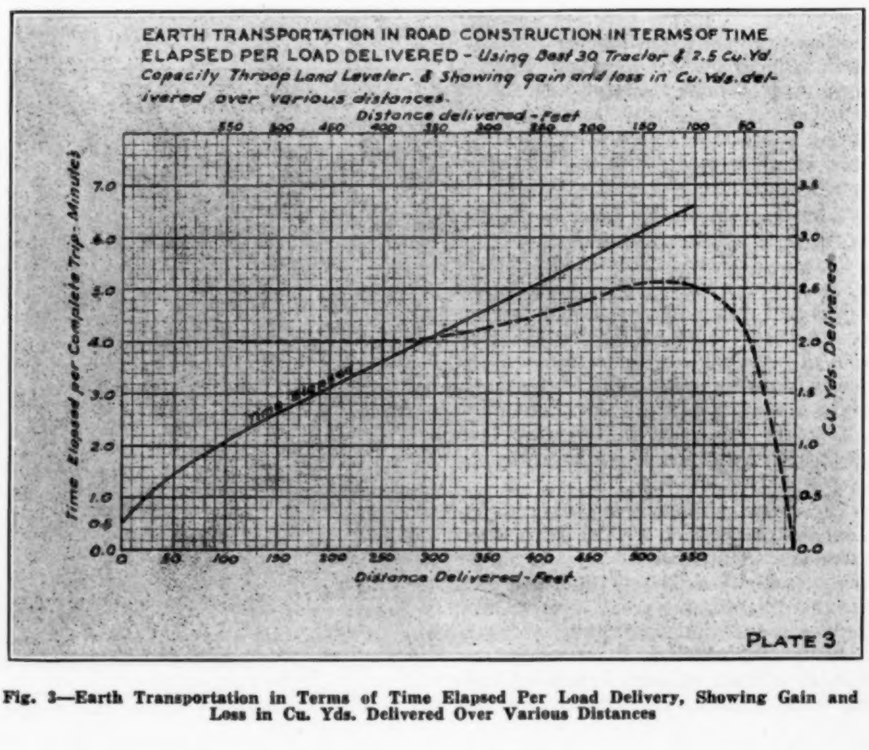


Fig. 3—Earth Transportation in Terms of Time Elapsed Per Load Delivery, Showing Gain and Loss in Cu. Yds. Delivered Over Various Distances

averaged from more than two hundred observations under differing conditions.

Length of Economical Hauls.—From the graphs it would appear that:

(1) The Best-30 and 2.5 cu. yd. leveler is not economical for deliveries exceeding 250 ft.

(2) The Best-60 with either a 3.5 cu. yd. or 5.0 cu. yd. leveler attains its maximum efficiency in hauls over 100 ft. and up to 400 ft. in average dry soils.

(3) The Best-60 with a 5.0 cu. yd. leveler, transporting damp earth, is not efficient under 250 ft., due to slow pick-up of load, but will deliver more yardage from 450 ft. to 750 ft. than it will with dry soils, due to better cohesion of damp earth particles.

Comparative Costs.—From careful observation and comparison of parallel cases the writer is convinced that under average workable conditions, where borrows or wastes are not too far located from the work, subgrades such as commonly cost from $2,000 to $3,300 per mile when built with team equipment may be constructed for from $1,800 to $3,000 per mile through use of caterpillar tractors with land levelers for transporting earth in construction.

New Type Perfex Radiator for Diesels

A new type of radiator for Diesel and heavy duty engines has just been announced by the Perfex Corporation. The new feature is the mounting of an unusually large air circulating fan directly on the radiator frame. This is completely protected by a screen as shown and shrouded to insure uniform air circulation over the entire radiator. The fan is carried on anti-friction bearings and provided with a large enough belt pulley to insure positive fan operation over long periods without attention, it is said. On account of the large size of both radiator and fan it is usually very difficult to mount the fan on a Diesel engine and at the same time locate it where the radiator may be efficiently cooled.

These radiators also incorporate the latest developments in removable core sections. Each unit is securely held in place by four nuts. This permits removal and repair of any individual section without dismantling the radiator and also continued operation of the power plant for reasonably long periods while a section is out. An alternative is to carry a reserve section which can be put in the place of a damaged section in a few minutes.

The cores of these heavy duty radiators are made from copper to prevent corrosion. The tubes are oval in shape, have double lock seams that are said to make them burst-proof when frozen. Copper, heat radiating fins, strengthened by reammed front and rear edges, furnish a most efficient design of cooling unit. These are baked onto the tubes in ovens that have automatic temperature control in order to insure uniformity of product. To supply the industrial field, a full line of these radiators are now available for prompt delivery in sizes from 50 to 350 hp.

New Spark Control for Climax Engines

The Climax Engineering Co. of Clinton, Ia., has perfected and now offers for sale on its heavy duty industrial engines a new Automatic Spark Control.

This new spark control operates from the suction in the intake manifold. As the variation in pressure in the intake manifold is proportional to the load imposed upon the engine, the ignition is always timed correctly, no matter how the power varies on intermittent loads, and by timing the spark automatically, this new device does what operators could not possibly do by hand, according to the manufacturers.

There is little loss of power and the fuel consumption decreases to a point where a saving of 10 per cent on fuel is attained on intermittent loads, such as are encountered in earth moving machinery, locomotives and similar classes of equipment, it is claimed, and that it will reduce spark knocks and reduce wear on bearings.

The Automatic Spark Control can be quickly installed in the field on any model Climax engine. The small additional cost of installation is offset in a few months by the saving it affords in fuel consumption. It can be applied by Climax Service Stations.

This is one of the many new exclusive features that the Climax Engineering Co. is incorporating on its engines to meet the present day need for modern and up-to-date power equipment.

Pan-American Division of A. R. B. A.—The proposed formation of a Pan-American Division of the American Road Builders' Association has been favorably received as a means for early completion of highway communication between South America and the United States. Charles M. Upham, director of the association, has discussed the formation of such an organization with engineers and officials of British Honduras.

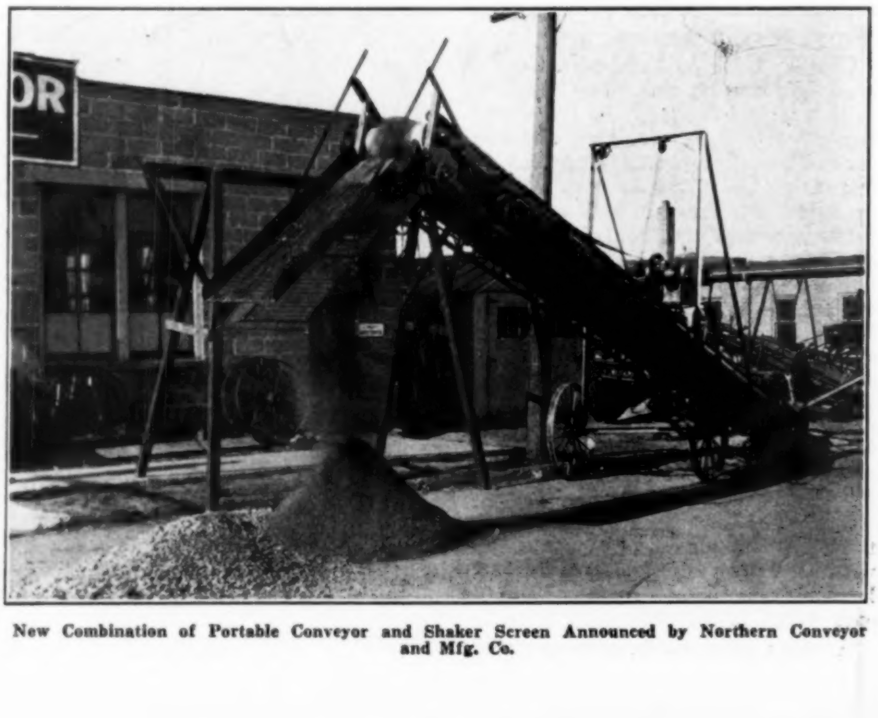
New Combination Conveyor and Screen

The photograph on this page shows the new Northern portable conveyor in operation with shaker screen attached.

This equipment has recently been patented by the Northern Conveyor & Mfg. Co., of Janesville, Wis. The combination of their style of shaker screen with many of their portable conveyors results in a complete loading and screening plant of the portable type on two wheels that may be moved from place to place on a moment's notice by hitching on behind a truck or wagon.

It carries its own power plant, requires no assembly when moved to a new location or no mechanical labor to make ready for moving. It is a complete, portable plant—without question the simplest on the market, according to the manufacturers. It does for a small gravel pit or a contractor everything that large, heavy and cumbersome conveyors and screening equipment with hoppers will do, yet at the same time there is no erection involved as the equipment comes to a customer completely set up in every respect, it is said.

Its cost is very small and the shaker screen or the conveyor may be used separately and quickly detached from one another for their respective uses.



New Combination of Portable Conveyor and Shaker Screen Announced by Northern Conveyor and Mfg. Co.

The Highway Contractor and His Bill

Billing for Extras Discussed Before Meeting of Central Board of A. G. C.

By J. L. HARRISON
Highway Engineer, U. S. Bureau of Public Roads

WHEN you are awarded a paving job, you are asked to sign rather a brief contract in which there appears a short sentence making the plans and specifications part of this contract. The plans are a big roll of blue prints. The specifications fill a good sized book. Now, that contract, though many of you may never have suspected it, is a statement of mutual agreement. The Party of the Other Part wishes certain specific things done—certain specific results accomplished, which things you agree to do and which results you agree to accomplish — for a specified consideration. Indeed, the essence of a contract is agreement. You have agreed with the Party of the Other Part as to what is desired. But, you can only agree about specific things, and then only on the basis of mutual under-understanding as to what the words in which the agreement is drawn mean.

It is, in short, a general legal assumption of wide application that in agreeing to a bargain which uses old and established words, phrases, clauses or provisions with them, the parties do so on the basis of the interpretations of these words, phrases, clauses and conditions which have controlled in that region in the past and so have come to measure more exactly, the kind and the amount of work to be done. In other words, a contract using old terms in the old way continues in force the established practices.

A Legal Interpretation.—Let me give you an illustration of what this means. The speaker was employed for some years as an engineer with the Bureau of Public Works in Manila. A good deal of galvanized corrugated iron was used there for roofing. For years all of it was supplied under a clause reading substantially as follows: "The galvanized corrugated iron used on this building shall be of the best quality obtainable in the Philippine Islands."

Under this clause the use of one particular brand of roofing iron had become practically universal though this was not, in fact, the best brand available. Indeed, it often was rather a failure—so much so in fact that an effort was made to enforce the use of other brands believed to be more durable. Our legal department ruled that without any regard to the merits of this roofing iron and without any regard whatever to whether it was then or ever had been the best roofing iron obtainable in the Philippine Islands, the specifications had come to mean neither more nor less than that this one particular brand of iron could be used, and that a contractor could not legally be put either to expense or inconvenience to supply some other brand as long as that specification remained in force. Our lawyers also held that even a change in the specifications would not serve as ample notice that a better roofing must be used, because the fact that contractors did not carefully scrutinize the details of a voluminous specification had had the effect of creating here, also, a custom which ought to be recognized if the mutuality that is at the basis of the contractual relation was to be maintained—a custom which made it essential that special and specific notice prior to the receipt of bids be given before any change in the specifications which would adversely affect the cost of construction would be binding.

Contract Not Alterable.—These matters are referred to as a natural approach to the remark that neither party to a contract may change the terms, whether written, or established by custom, without further mutual agreement. In other words, the contractor cannot lawfully be required, at his own expense, to abandon a customary method because the engineer in charge of his work believes another method better, even though in the engineer's opinion the phraseology of the specifications would make the proposed method an appropriate method. He bid with the customary practices in mind and these established his responsibility under the contract. The preference of the engineer is no part of that very important document, the contract.

Supplementary Agreements.—On the other hand, supplementary agreements—you all know this document in its popular form, the change order—may be made without limit. The basis of most supplementary agreements—that is, of most change orders—is in the desire, the preference or the necessity of the Party of the Other Part. You have agreed to do certain specific things, to secure certain results, but these have now been found not exactly the things or exactly the results desired and, in the interest of the Party of the Other Part, you are asked to agree to do other things or to secure other results than those to which you originally agreed. This is perfectly proper—purely a business proposition—but as these changes are asked because they are in the interest of the Party of the Other Part, they should be agreed to only on the understanding that they will not prove unprofitable. This, too, is merely a matter of business. Most engineers of any standing much prefer that contractors make a reasonable profit, so the problem for them, as for you, is to determine the real cost of making the changes, after which the matter of a fair profit is not difficult to adjust.

Get It in Writing.—I have tried to lay some emphasis on the fact that the contractual relation is a mutual relation and that any change in the details of a contract as originally drawn, while they should be acceptable to both parties, are after all merely business matters, because there appears to be some disposition to feel that a contract deals in generalities and that, therefore, if it is followed in a general way justice is done. The fact is that in its very nature, and to its last detail it is as specific as words can make it and that any change in it—no matter how minor this change may be—may introduce conditions not contemplated when the contract was drawn; changes which, as a matter of ordinary business practice, demand financial recognition and adjustment.

This, of course, applies quite as much to method of operation as it does to the amount of work or the order of its execution. Whatever is a modification of the terms of a contract that alters the cost of executing it, whether these terms are clearly established by the plans and specifications or arise from the customs which have governed the interpretation of the terms and provisions of the specifications in the past, is a change which justifies a modification in your compensation.

Departures From Practices. — The matter is put in this way, because while it is generally recognized that a change from the plans calls for a change order, it is not as generally recognized that a modification in the interpretation of the specifications or in the generally accepted job practices which have developed under these specifications, also requires a change order and justifies a bill for modified compensation. And in using the word "justifies" I am using it advisedly. You agree to do one thing, but are asked to do something else. The original agreement was a matter of business both to you and to the other party to the agreement. The change also was a matter of business Finally, the recovery of the cost of making the change is a matter of business. In all of these matters it must be presumed that whatever action is

taken is founded on reasonable judgment as to what, under the circumstances, is required to be done. You, as a contractor, comply with what the judgments of those responsible think necessary. Then as a business man you endeavor to find out what compliance costs you and to bill accordingly. This is the business side of it and about all there is to it unless one adds, as the facts entirely warrant, that the question of whether the results of this year's work will be written in black or red is likely in no small degree to depend on the care with which you handle this matter.

Must Be Written.—On the other hand, no modification of a written contract is of much standing unless it is reduced to writing. If the engineer wishes a new method used in handling the cement, have him put it in writing and have him sign it before you execute it. If he tells you to stop the mixer or change the mix or alter your mixing time or in any other way interferes with what you understand to be the agreement you have signed, get the change order in writing and give notice promptly in writing that it will be executed at the cost of the Party of the Other Part. Leave nothing to memory. The best memories fail very often, so often that even if it was proper, legally, to work on the basis of memory, it would still be inexpedient to do so. But memory and conversation obtain scant credit when a written contract is under review.

A change order is no order at all unless it is reduced to writing, so you have no protection whatever in the execution of changes not called for in writing and ordinarily cannot enforce collection even of the cost of executing them.

No Obligation.—By the same token, you are under no obligation to pay even the slightest attention to any order that is not in writing. Legally, no order has been given until it has been given in writing. An appreciation of this is vital in the work of both the constructor and the engineer. But before you can collect the cost of executing a change order, to say nothing of obtaining a profit on it, you must know the origin of cost, for if the cost is to be recovered, its amount must be known in such detail and with such exactness that there can be no escaping the facts as you present them. Let us see, then, what information ought to be collected—what fields are involved when change orders are received.

On a paving job there are at least six important points where cost can be affected. Two of these involve the materials used.

1. The materials may be made to cost more than was anticipated.

2. The yield from the materials may be less than standard.

Changing Material Source. — Change orders which affect the source of supply and which affect the amount used per batch and in this way affect the yield—this is, the amount of pavement laid per cubic yard of aggregate or per sack of cement, fall in this category. Not long ago the speaker was looking over a job where the contractor was facing a steady overrun of about 10 per cent in his cement because of the rather extreme bulking of his fine aggregate. The engineer had refused to recognize the fact of this bulking which, under the prevailing specifications, he probably had perfect right to do. The sand was satisfactory, the concrete was satisfactory. He obviously had no reason to desire a change, and as the interests of the Party of the First Part were not suffering, he had no particular reason to agree to a change. Finding that this attitude—which mind you, was legally sound—existed, the contractor, as was his right, sought to relieve the situation by purchasing a sand that would not bulk so badly—a sand which, when combined with the coarse aggregate used on that job, would develop a proper yield. But this the engineer immediately prohibited. Now, had the contractor required that that order be given in writing, he would have been able to collect the cost of the over-run he continued to face through that job. The contract gave him wide latitude in the selection of materials and the change order had reduced this latitude. In theory, at least, this order was issued in the interest of the Party of the Other Part and because it was issued in the interest of the Party of the Other Part, it was a reasonable basis for a just claim against the party of that part.

Nor was the extra cost of materials the whole cost which should have been billed. It costs not far from $400 a day to operate a paving outfit—labor about $200 a day; equipment depreciation, say $100; operation—that is gas, oil, repairs, etc., with overhead, another $100. These are, of course, very general figures. Your job must be scrutinized rather carefully if you are to bill on this basis in order to obtain a more specific figure. However, your accountants can determine what the figure is. Commonly, it does not vary a great deal from job to job.

A Study of the Cost.—Now let us see what should have been charged for the execution of that order. In the first place, the over-run in the cement was 1,200 sacks per mile. At 50 cents per sack this amounted to $600 per mile. In the next place—I will not go into the details of the matter her—there was an over-run of about 125 cubic yards of stone per mile, which at $3 per cubic yard, was $375, and an over-run of about 60 cubic yards of sand (due to bulking) which, at $2 per cubic yard, was $120 per mile, making a net increase in the cost of aggregate of about $255 per mile. On that job production was at an average rate of about 700 feet a day, so a little over 7½ days were required to lay a mile of pavement. But the run is governed by the number of batches that can be handled. No more work would have been required in handling full batches than was required in handling the 90 per cent batches which were used. Had the yield been standard these batches would, therefore, have produced about 770 feet of pavement and laying a mile of pavement would then have taken a little more than 6.8 days. The difference—0.7 day per mile of pavement laid—represents the extra cost of operation resulting from the low yield, or 0.7x$400, which is $280 per mile. Beside this, the concrete was so brash that two extra men had to be used all of the time in finishing it, which, at $3 per day per man, was $45 per mile.

The Bill.—We now have the nature of the bill that should have been rendered pretty well outlined. It would have read somewhat as follows:

To extra cement per mile......$	600.00
To extra aggregate per mile..	255.00
To labor, equipment depreciation, equipment operation, labor, etc., required by reason of short batch, per mile	280.00
To special labor required because mix was brash............	45.00
Total extra cost per mile....$	1,270.00
Concrete laid after order was received 8 miles....................	8
Total cost of order................	$10,160.00
Profit at 15 per cent................	1,524.00
Amount due............................	$11,684.00

This is only a single illustration of how an order affecting the materials may affect cost. More recently the speaker visited a job where the mix had been changed. Both the sand and the coarse aggregate — in this case gravel—met the controlling specifications. In spite of this, the yield was high by as much as from 5 to 7 per cent. To obviate this a cubic foot of gravel was taken out of the batch. As a result production was dropped from about 240 feet per 100 five-bag batches to 225 feet per 100 five-bag batches. This action made it necessary to increase the use of cement by some 820 bags per mile, which, at 50 cents per bag, cost $410. The amount of sand used was increased about 60 cubic yards —worth about $120 per mile. The use of gravel was not appreciably modified. Decreasing the size of the batch increased the time required in laying a mile of pavement about one-half a day, which, at $400 for labor, depreciation, operating cost, etc, amounted to $200. These items—cement $410, sand $120, labor, etc. $200, amount to $730 per mile of pavement, or if a profit of 15 per cent is added, to practically $840 per mile, the claim the contractor ought to have filed for compensation for having that cubic foot of gravel taken out of the batch.

Four Other Items.—It would be easy enough to spend the balance of the time allotted to this address in further discussion of change orders affecting the materials, but this hardly would be advisable. There are four other places at which cost may be seriously affected:

1. The rates of wages paid labor may be increased.
2. The number of men required may be increased.
3. The number of hours worked per day may be decreased, or
4. The rate of output may be decreased.

Of these, the first, the wage rates may be dismissed with the observation that change orders seldom affect wage rates.

Orders affecting the work done per day are rather common, though they often escape notice as such. Because this fill has not settled an order is issued to skip it—1,200 feet—until further orders. Or the approaches to the bridge over Pee Creek require further compaction. These matters were not noted in the plans. They involve work done by another contractor. In the first case two hours were spent in moving across the 1,200-ft. gap. In the second a day and a half was lost in getting around the bridge because the approaches would not carry the mixer. The men, of course, had to be paid. Is the proper charge two hours at $40 in the first case, and one and a half days at $400 a day, in the second case? By no means. Time will be lost in getting back to these set-ups. Perhaps pumps and pipe lines must be relaid. Transportation conditions may be entirely different than they were when the work would have been done had the contract been followed. All of these are just and proper items in the bill of costs.

Change in Schedule.—Not long ago while we were driving out to see a paving job a thousand miles or more from here, the contractor remarked that after his material yard was located and he was about ready to begin paving operations on the mile over which we were driving, the engineer had asked him to delay work here as long as possible as the fill had not fully settled. Asked what he expected to charge for this change in his plans, the contractor, rather amused at the idea of rendering a bill for the execution of such a change order as this, replied that while he never had made a calculation of the cost of executing this one, he had never thought of charging anything, though he supposed that it might cost him a couple of hundred dollars! However, keeping the engineer in good humor would, he surmised, be worth that much at least. Now that engineer happens to be one of the best humored men in a very large state, as well as a good business man, so there being no particular need of doing anything to keep him in good humor, and this being quite an everyday business matter, we began to examine that change order a little more closely. The contractor's plans had made this work the third mile south of his first set-up. The change order made it the fifth mile north of his second set-up. Hauling was being done under a sub-contract at 30 cents a batch mile, so the cost of hauling was in this case raised from 90 cents a batch to $1.50 per batch. The increase —60 cents a batch, applied to the 2,350 batches required for a mile of pavement, amounted to a mere bagatelle of $1,410. Moreover, the subcontractor was not required to furnish more trucks than enough to keep up the production against a four-mile haul. There was, therefore, every prospect that there would be an inadequate truck supply on this mile, with the result that an extra day's work would have to be done on it—at a cost $400. The water supply lines as planned would not reach this mile of pavement when poured from the second set-up. Two miles of pipe had to be laid and taken up to get water to this work. As this was heavy pipe, the cost of handling it amounted to $150 a mile, or to about $300. Freight on aggregate sent to the second set-up which was on a different railroad was 20 cents a ton higher than at the first set-up. This, at 4,000 tons to the mile amounted to about $800. The total of these items, $2,910, was only the cost the engineer's order seemed likely to generate. Adding a fair profit of say, $450, raised the amount of the perfectly reasonable bill for this change to over $3,350!

Not Exceptional.—Cases of this sort are not exceptional. As a matter of fact, they are of common occurrence. Naturally, they do not often run into figures as large as this, but here and there time is lost because change orders or special conditions not contemplated when the contract was drawn are created, and as these changes are made in the interest of the Party of the Other Part, it is merely a matter of ordinary business management that you recover the cost of executing them.

Change orders may also affect the number of men employed. On the whole, this is not a source of serious loss, for the number of extra men used in executing a charge order can be determined both readily and accurately. Merely to mention this field is therefore sufficient.

But when the last field is examined, the change orders which adversely affect rates of production, the most annoying, the most numerous, and at the same time the group probably most destructive of profit, is encountered. The cost of these is difficult to collect because it is hard to show conclusively that the rate of output has been affected—harder still to show that the adverse effect on the rate of production was unavoidable. And even if both of these are accomplished there still remains the problem of showing what the cost has been, for the concept of a production organization as a constant cost organization is not as generally accepted as it ought to be. Not long ago the speaker learned of a case in which the contractor was directed to modify his practice in handling cement. It had been the practice in that region to empty the sacks onto the aggregate at the cement house. This practice still governed in most places. There had been no change in specifications. The order required that the coarse aggregate be first dumped into the truck after which it was required that the truck proceed to the cement shed and load cement. The truck was then required to return to the hoppers for sand to complete the batch. This required each truck to make an extra trip through the material yard and because of the time used in this way, necessitated the use of an extra truck in order to maintain customary rates of production. But, while the extra truck was being secured, there was a loss of production during a period of two days. This loss of production probably amounted to about 6 per cent, as fifteen trucks were in use. If the cost of production is taken at $400 a day, the loss here was 6 per cent of $400 or $24 a day for each of two days, say $50. Of course this was merely a slight addition to the cost of one extra truck for the balance of the season, a truck which as far as its value in promoting production was concerned might as well have been kept running round in the material yard. Some 75 days' work were done after this order was received, so the bill could properly have read:

To one truck for 75 days at $10	$750.00
To loss of production while securing additional truck	50.00
Total	$800.00
Profit at 15 per cent	120.00
Total charge	$920.00

New Methods.—It is even harder to bill for the execution of new methods required under change orders. Not long ago the speaker visited a job where the contractor had been ordered to use a longitudinal float. The effectiveness of this tool has no bearing on the two pertinent facts; first, that its use was not required by the specifications and, second, that a change order forced the contractor to use it. He was told that its use would not increase his payroll and I believe that eventually he managed to adjust operations to a point where this was substantially true, but in getting to that point it had, for a time, been necessary to employ extra men. Moreover, after the device was installed the rate of production had, for some days, to be held down so that the men operating the longitudinal float could keep up. Certainly, as the extra men employed and the production lost while this new style of finishing was being mastered, were expenses incurred solely in the interest of the Party of the Other Part, it can hardly be questioned

that they are a just charge against the Party of the Other Part. Admittedly, the data to support a charge for the execution of an order of this sort must be collected carefully but it will, I am sure, be generally agreed that it should be collected and a bill rendered.

Too Rigid Inspection.—Production is sometimes obstructed by too rigid inspection. I have often seen jobs continually held up for short periods by an inspector who insisted that the drag template should ride free over the subgrade though it is customary to give a little tolerance here, and custom, it must be remembered, is as valid as anything if it can be proved, and where the worst cases of this kind have been observed there is a specified tolerance of one-fourth inch. The speaker was present last year when an inspector shut down the mixer for half an hour because he found the subgrade 75 feet ahead of the mixer half an inch high, and this in spite of the fact that he had cleared it himself. On another occasion, I spent all of one afternoon watching operation on a job where the operating cycle consisted in pouring four batches of concrete after which the mixer was run ahead about 9 feet dragging the planer. The subgrade was a little high so one wheel of the planer would generally ride high. The mixer would then be run back and forth until all four wheels on the planer rolled. Now, the subgrade could have been in a little better shape though it ought, in fairness to the contractor, to be remarked that it was in excellent condition, except for being a little higher than could conveniently be trimmed off. But the process required by the inspector in reducing this high subgrade on the one hand gave no tolerance, and on the other was cutting the rate of production at the mixer to half of what it would otherwise have been. In cases of this kind the same general practice holds—that the contractor is entitled to compensation for any extra effort he is called on to make. The problem, as you all see, is to make the nature and the amount of the extra cost apparent. Cases of this kind are peculiarly hard to deal with, for the contractor's men were careless and the inspector improperly exacting.

Looking over the cases cited above and the numerous cases there is no time to mention in the course of a brief address of this sort, one fact stands out—that in the execution of change orders, large items of expense, often the principal item of expense, are indirect; that is, they arise from the effect of the change order on the rate of production, on the yield, on the hours worked, etc. This does not make them any less true items of expense, but it does make them more definitely difficult to appraise correctly and does, for that reason, make it the more necessary that exact records be kept from which to render bills in detail with a full explanation of each item covered.

Billing for Changes.—I will hazard the guess that no one of the gentlemen present has ever rendered a bill for extras because he was required to omit a section of pavement and come back to it later. Yet, a perfectly sound bill for extras lies in a large percentage of all cases of this sort. And, do you render bills for extras in connection with other engineering changes? Last summer a contractor I know very well was running along at a rate of about 900 feet of pavement laid per day when the engineer decided that a street intersection had been staked improperly and ordered 300 feet of forms torn up just in front of the mixer and the grade raised from nothing to 4½ in. Result: half a day's time lost. The men had to be kept so they were paid, though under the circumstances they could do nothing of any real value. A few days later it was a change in section at a railroad crossing. Another half day lost. A week later it was a mistake, a vertical curve was omitted in staking out the pavement, and within a short distance subgrading increased from an inch or two to about 2 feet—another half day lost. A week later a sudden change in plans took two feet off the top of a 700-foot gumbo fill not that far ahead of the mixer. In spite of laying duck boards, over the soft gumbo this change exposed, this mixer lost a day here to say nothing of the duck boards which were hopelessly broken up and the truck that was wrecked. Do you bill for the loss of time, the materials, and the breakage such matters as this involve? Contracting is a business proposition. The execution of change orders is a business proposition—a part of your business. They affect the volume of your business and ought not in any event to affect unfavorably the amount of your profit.

Finally, let me observe again that while bills for extra cost are lawful, right and proper—and can be enforced when supported by proper records and correct data—an absolute prerequisite of any claim is an order in writing. Do not, under any circumstances, fail to obtain this document if any expense, direct or indirect, is to be involved. In short, do not accept any order affecting cost not presented in writing. A verbal order is not an order. No contractor can afford to overlook this fact.—*Lone Star Contractor.*

State Road Equipment Painted Bright Yellow.—The maintenance shops of the Ohio Division of Highways have painted all road equipment a bright yellow. With over 3,000 separate units at work on the roads, traffic accidents have occasionally occurred in the past and this step has been taken to give the units increased visibility and at the same time accomplish the annual repainting.

Motor Vehicle Registration in 1927

More than twenty-three million motor vehicles were registered in 1927, according to information collected from state registration authorities by the Bureau of Public Roads of the United States Department of Agriculture. The total registration of 23,127,315 vehicles was composed of 20,230,429 passenger vehicles and 2,896,886 motor trucks and road tractors. This registration represents an increase of 1,125,922 vehicles or 5 per cent more than in 1926. Using the population estimate for the middle of last year, there was one motor vehicle for every 5.13 persons.

States with a registration increase of 10 per cent or more are North Carolina, South Carolina, Utah and Arizona. States with a numerical increase of over 50,000 are New York, California, Ohio, Illinois, Texas and New Jersey.

As in other recent years, motor vehicle registration receipts constituted a substantial contribution to funds for road construction. The total receipts from registration fees and licenses amounted to $301,061,132. These funds were allocated as follows: Collection and administration $14,876,410; State highways, $189,985,289; local roads, $53,577,893; payments on state and county road bonds $38,087,598; and for miscellaneous purposes $4,533,942.

The total motor vehicle registration by States was as follows:

Alabama	243,539
Arizona	81,047
Arkansas	206,568
California	1,693,195
Colorado	268,492
Connecticut	281,521
Delaware	47,124
Florida	394,734
Georgia	300,635
Idaho	101,336
Illinois	1,438,985
Indiana	813,637
Iowa	704,203
Kansas	501,901
Kentucky	285,621
Louisian	255,000
Maine	163,623
Maryland	270,935
Massachusetts	694,107
Michigan	1,154,773
Minnesota	646,682
Mississippi	218,043
Missouri	682,419
Montana	112,735
Nebraska	373,912
Nevada	25,776
New Hampshire	96,009
New Jersey	712,396
New Mexico	59,291
New York	1,937,918
North Carolina*	430,499
North Dakota	160,701
Ohio	1,570,734
Oklahoma	503,126
Oregon	244,572
Pennsylvania	1,554,915
Rhode Island	118,014
South Carolina	199,635
South Dakota	169,552
Tennessee	294,567
Texas	1,111,407
Utah†	93,976
Vermont	79,527
Virginia	337,607
Washington	384,583
West Virginia	245,819
Wisconsin	698,289
Wyoming	51,955
District of Columbia	111,680
Total	23,127,315

*Last six months of year's registration only, as year commenced July 1.

†Preliminary data, subject to revision.

Determination of Proportions of Constituents in Concrete

Proposed Laboratory Method Described in Public Roads

Reported by L. G. CARMICK
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THERE are many occasions when it is of considerable importance to know the relative proportions of cement, sand, and stone that were used in the building of some concrete structure. If concrete proves good, we want to know why it is good, and if it is bad our first thought is usually a question as to the proportions used in making it. In practically every laboratory where engineering materials are tested samples of concrete are sent in from time to time and the chemist is asked to determine their proportions. Many of these cases have a legal aspect in that the concrete is suspected of being other than it should be. Perhaps the contractor is accused of skimping the mix. In such cases a dependable analysis is of the highest importance. At first thought it appears rather a simple matter to make such an analysis, but actually it is very difficult. This is true notwithstanding the fact that considerable work has been done on the problem in a number of good laboratories.

A Difficult Study.—The difficulties involved are of several sorts. In the first place there is apt to be considerable segregation even in well-mixed concrete and a small sample can not be considered as representative of a large mass. When we endeavor to avoid this error by taking a large number of samples we are met by difficulties in the analysis itself and the lack of an entirely satisfactory method. The cement, sand, and stone are all composed of about the same constituents—silica, alumina, and lime, together with some others that are present in lesser amount. The proportions differ in the different materials, and while it is easy enough to tell how much lime the concrete contains it is not easy to say how much of it is from the cement and how much from the sand or stone.

Bulletin 61 of the Iowa State College, Estimation of the Constituents of Portland Cement Concrete, by George W. Burke, offers a method that appeared to be highly promising, and work reported in this paper has been an effort to determine the degree of accuracy which can be secured with it.

Outline of Method.—Briefly, the method is as follows: A sample of the concrete, weighing from 1,000 to 1,500 grams, is broken into fragments of not more than 2 inches in size and heated in a muffle furnace for about three hours at a temperature of 600 to 700 deg. C. This causes dehydration of the set cement and should make it easy to separate and clean the coarse aggregate by scraping or brushing. All material below one-quarter inch in size is called "sand-cement fixture." A sample of this is put aside for analysis and from the remainder an effort is made to secure a representative sample of the sand. This is done by sifting and rubbing in a mortar with a rubber-covered pestle. The process is described in detail in the bulletin. The sand-cement and the pure sand thus obtained are each analyzed for silica and for lime. A calculation can then be made of the proportions in the sand-cement mixture with either of these data and assuming the percentage of lime or silica in the cement.

For example, representing the proportional weight of the cement present by C and the proportional weight of the sand by S, a unit weight of the mixture can be expressed by

$$C+S=1 \qquad (1)$$

Knowing the lime content of the cement, sand, and sand-cement mixture we can write

$$P_cC+P_sS=P_m\ (C+S) \qquad (2)$$

in which P_c=per cent CaO in the cement,

P_s=per cent CaO in the sand,

P_m=per cent CaO in the sand-cement mixture.

Solving equations 1 and 2 simultaneously, the values of C and S may be calculated. In the same way calculations may be made on the basis of the silica content of the materials. In using this method when a sample of the original cement is not available it is necessary to assume an analysis for it. Twenty-one per cent silica and 62 per cent lime are considered as about the average.

An Important Limitation.—Preliminary experiments, made by the Bureau of Public Roads but not given in detail here, have shown that when the coarse aggregate is limestone or dolomite the results obtained by this method are very uncertain. Baking the sample at 600 to 00 deg. C partially calmost limestones, and if a lower temperature is used it is hard to disintegrate the concrete. Many small fragments of the limestone are sure to be included with the sand-cement mixture and seriously impair the accuracy of the results. Some other stones, such as granites which are not thoroughly sound, are easily broken down after heating.

To obtain even approximately correct results by this method it appears to be necessary that the coarse aggregate be a rock that is not much affected by the heat used, not easily crumbled, and noncalcareous, and also that the sand be noncalcareous and not much affected by dilute hydrochloric acid.

The Method Tested.—As a test of the method, 10 small cylinders were made of a mortar consisting of 1 part cement and 2½ parts Potamac sand which meets the above conditions. These cylinders were analyzed and the results are given in Table 1. The first three cylinders were treated exactly in accordance with Burke's dry method. All of the sand from cylinders Nos. 4, 5, 6, and 7 were mashed with a 5 per cent solution of hydrochloric acid and the sands from cylinders Nos. 8, 9, and 10 were washed with water. It seems

Table 1.—Test results of analysis of cylinders made with 1 part cement and 2.5 parts Potomac sand

Analysis of Materials

Per cent	Sand	Cement	Sand and cement mix (theoretical)
SiO_2	89.90	20.80	70.16
CaO	.50	59.60	17.39

Analysis of Mortar Cylinders

Cylinder No.	Sand and cement SiO_2 Per cent	Sand and cement CaO Per cent	Sand SiO_2 Per cent	Sand CaO Per cent	Cement to sand, parts: Based on true lime content of cement	Cement to sand, parts: Lime content of cement assumed as 62 per cent	Remarks
1	70.44	16.23	91.38	1.54	1:2.95	1:3.11	Sand brushed dry.
2	70.75	16.55	87.80	3.34	1:3.25	1:3.42	
3	70.40	17.22	88.58	2.74	1:2.92	1:3.10	
4	70.73	16.69	95.14	.30	1:2.60	1:2.76	Sand washed with dilute HCl (5 per cent).
5	71.83	15.90	94.73	.13	1:2.77	1:2.92	
6	70.31	16.85	94.55	.24	1:2.57	1:2.71	
7	70.21	17.06	94.00	.34	1:2.53	1:2.69	
8	70.87	16.41	90.17	2.50	1:3.10	1:3.27	Sand washed with water.
9	71.40	16.13	92.18	1.97	1:3.06	1:3.23	
10	71.17	16.40	91.20	2.22	1:3.05	1:3.22	

Table 2.—Test results of analysis of cylinders made with 1 part cement and 2 parts Potomac sand

Analysis of Materials

Per cent	Sand	Cement	Sand and cement mix (theoretical)
SiO_2	89.90	20.80	66.87
CaO	.50	59.60	20.20

Analysis of Mortar Cylinders

Cylinder No.	Sand and cement SiO_2 Per cent	Sand and cement CaO Per cent	Sand SiO_2 Per cent	Sand CaO Per cent	Cement to sand, parts: Based on true lime content of cement	Cement to sand, parts: Lime content of cement assumed as 62 per cent	Remarks
1	67.15	20.00	88.40	1.45	1:2.13	1:2.26	Sand brushed dry.
2	67.25	19.80	88.70	1.65	1:2.19	1:2.32	
3	67.20	19.85	89.00	1.55	1:2.17	1:2.30	
4	66.50	20.40	88.65	1.50	1:2.07	1:2.20	
5	66.95	20.10	93.25	.30	1:2.00	1:2.11	Sand washed with dilute HCl (5 per cent).
6	66.45	20.45	93.10	.20	1:1.93	1:2.03	
7	67.15	19.95	92.85	.25	1:2.01	1:2.13	
8	67.10	19.85	93.20	.20	1:2.02	1:2.15	
9	66.90	20.20	88.15	1.40	1:2.10	1:2.22	Sand washed with water.
10	67.00	20.25	88.65	1.45	1:2.09	1:2.22	
11	67.00	20.35	89.10	1.35	1:2.07	1:2.19	
12	66.55	20.05	88.55	1.50	1:2.13	1:2.26	

evident that it is necessary to wash the sand with acid, as otherwise it carries with it a considerable amount of cement. It is apparent also that a much greater degree of accuracy is obtained by using the true lime content of the cement (59.60 per cent) instead of an assumed value of 62 per cent. Calculations made on the basis of the silica content were so wide of the mark that they are not given.

Believing it possible to improve on the above results by greater care and attention to detail, another set of 12 cylinders was made from the same cement and sand, using a 1 to 2 mix.

The sands from the first four were brushed dry, those from the next four were washed with a 5 per cent hydrochloric acid solution, and those from the last four were washed with water. The greatest care was taken in the preparation of the samples and in the analyses. The results are given in Table 2 and show a considerable improvement in accuracy. It was again apparent that it is necessary to wash the sand with acid and to know the true line content of the cement. This series also showed that the silica content is far less reliable as a basis for calculations.

It is believed that this second series shows the maximum degree of accuracy that can be hoped for in the case of mortars when the conditions and materials are almost ideal.

Continuing the investigation, 10 concrete cylinders were cast, using the same sand but a different cement, and a 1:2:4 mix. The coarse aggregate consisted of clean siliceous pebbles 1 inch or less in size. The test results are given in Table 3. Again a great improvement is noted in those cases where acid washing was resorted to.

Conclusions.—The following conclusions are drawn from these experiments:

(1) It is of the utmost importance to have samples of the original constituent materials used in making the concrete. It is particularly necessary to know the true CaO content of the cement, as actual variation from an assumed value may introduce a considerable error.

(2) Calculations should be made on the basis of the CaO content of the cement. Those made on the basis of silica content are not at all reliable.

(3) Reasonable accuracy can not be secured unless the fine aggregate is siliceous and little affected by dilute hydrochloric acid, and the coarse aggregate a noncalcareous rock which will not be broken down by the necessary heating.

(4) Washing the whole of the sand with dilute hydrochloric acid secures greatly increased accuracy.

(5) The best results which can be obtained by this method are only approximate, since—

(a) Results having a high degree of accuracy can not always be obtained by the analyses of samples of known composition; and

(b) Small samples of concrete such as would be used in this method may not be truly representative of the mass from which they were taken.

(6) The limitations which have been pointed out and the lack of accuracy under highly favorable conditions show that this method is of practical value only when approximate rather than exact information is desired.

Emergency Oiled Sand Road

In December, 1926, a heavy flood destroyed nearly 2 miles of concrete pavement on the San Diego-El Centro road about 30 miles west of El Centro, Cal. The damaged road was paralleled by a broad expanse of sand in the Myers Canyon Wash, a strip of which was promptly oiled to serve as a detour pending reconstruction. Nominally 5 gal. per square yard of 60 to 70 per cent "fuel oil" was spread, but tests indicate that the actual rate of application was somewhat less than 4 gal. per square yard; the excess having been used to attain extra width. The oil was mixed with the sand by cultivation and grading to a depth of about 7½ in. By the end of January, 1927, the surface had attained a fair degree of consolidation. On Feb. 22 the center was supporting heavily loaded trucks and ordinary automobiles were running over the detour at 40 miles an hour. The edges, subjected to comparatively little traffic, were still soft.

A sample was taken on Feb. 13 for tests. All material passed the ¾ in. screen, 97.9 per cent passed the No. 3 screen, and 79.7 per cent passed the No. 10 sieve. The 10-mesh material had the following grading:

	Per Cent
Passing 10-mesh sieve	100.0
Passing 20-mesh sieve	61.0
Passing 30-mesh sieve	36.5
Passing 40-mesh sieve	26.6
Passing 50-mesh sieve	18.2
Passing 100-mesh sieve	8.6
Passing 200-mesh sieve	4.9

The oil content was 3.6 per cent of the total, or 4.5 per cent of the 10-mesh material.

The sand in this temporary road is coarser than any other treated soil described. The amount of silt and clay is negligible. The oil content is low, but the appearance of the road shows that ample was used.

Table 3.—Test results of analysis of cylinders made with 1 part cement, 2 parts Potomac sand and 4 parts gravel

Analysis of Materials

Per cent	Sand	Cement	Sand and cement mix (theoretical)
SiO_2	89.90	21.15	66.98
CaO	.50	61.10	20.70

Analysis of Cylinders

Cylinder No.	Weight of sample (grams)	Weight of stone (grams)	Weight of sand (grams)	Weight of cement (grams)	Sand and cement SiO_2 Per cent	Sand and cement CaO Per cent	Sand SiO_2 Per cent	Sand CaO Per cent	Proportions found	Remarks
1	1,040	575	321	144	67.20	20.15	90.90	1.85	1:2. 23:4. 00	Sand brushed dry.
2	1,115	660	319	136	66.15	19.85	91.45	2.15	1:2. 34:4. 85	
3	1,260	740	366	154	65.70	19.75	88.70	2.30	1:2. 37:4. 80	
4	1,075	635	295	145	65.95	20.40	93.15	.35	1:2. 03:4. 38	Sand washed with HCl (5 per cent).
5	1,210	680	357	173	68.05	20.10	92.75	.20	1:2. 06:3. 93	
6	1,315	760	367	188	67.75	20.75	93.25	.20	1:1. 95:4. 04	
7	1,175	635	355	185	66.45	21.05	93.40	.15	1:1. 90:3. 43	
8	1,225	735	333	157	67.10	21.10	90.85	2.20	1:2. 12:4. 68	Sand washed with water.
9	1,085	610	333	142	66.25	19.60	89.10	1.85	1:2. 34:4. 30	
10	1,145	640	346	159	66.00	20.35	90.15	1.70	1:2. 17:4. 02	